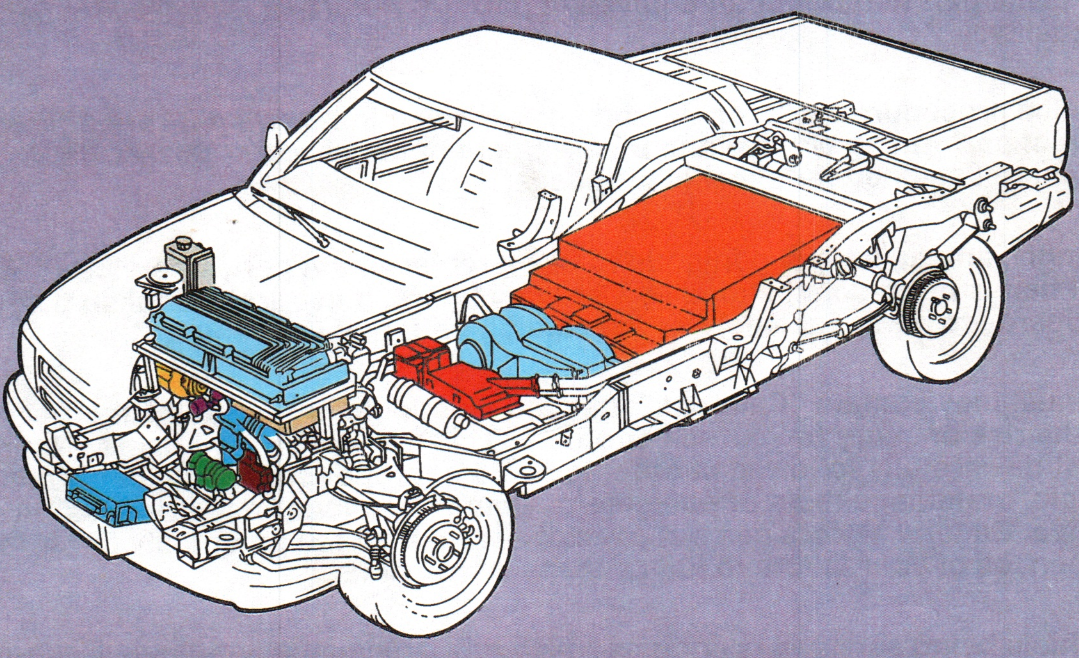
Chevrolet S10
Electric Truck

GM ALTERNATIVE FUELS



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18005.01-2

Caution

In order to reduce the chance of personal injury and/or property damage, carefully observe the instructions that follow.

Service information provided by General Motors Corporation is intended for use by professional, qualified technicians. Attempting repairs or service without the appropriate training, tools, and equipment could cause injury to you and others. This could also damage the vehicle, or cause the vehicle to operate improperly.

Proper vehicle service and repair are important to the safety of the service technician and to the safe, reliable operation of all motor vehicles. If you need to replace a part, use the same part number or an equivalent part. Do not use a replacement part of lesser quality.

The service procedures we recommend and describe in this manual are effective methods of performing service and repair. Some of the procedures require the use of tools that are designed for specific purposes.

Accordingly, any person who intends to use a replacement part, a service procedure, or a tool that is not recommended by General Motors, must first establish that there is no jeopardy to personal safety or the safe operation of the vehicle.

This manual may contain "Cautions" that you must observe carefully in order to reduce the risk of injury to yourself or others. This manual also contains "Notices" that must be carefully followed in order to avoid improper service that may damage the vehicle, or damage tools or equipment. These "Cautions" and "Notices" are not exhaustive. General Motors can not possibly warn of all the potentially hazardous consequences of your failure to follow these instructions.

If the vehicle being serviced is equipped with a Supplemental Inflatable Restraint (SIR), refer to the "Cautions" in the following service manual section/service category type before performing a service on or around SIR components or wiring:

- Section 9 — Supplemental Inflatable Restraints, refer to "Cautions" under "On-Vehicle Service" and the SIR Component Wiring Location view, or
- Section — Body and Accessories, Sub-section - Restraints, refer to "Cautions" under "On-Vehicle Service" and the SIR Component Wiring Location view

Failure to follow these "Cautions" could cause air bag deployment, personal injury, or otherwise unneeded SIR repairs.

In order to help avoid accidental air bag deployment and personal injury, whenever you service a vehicle that requires repair of the SIR and another vehicle system, we recommend that you first repair the SIR, then go on to the other system.

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Chevrolet S10 Electric Truck

Foreword

This manual contains information about the systems and components used in a General Motors vehicle, the Chevrolet S10 electric truck. Always refer to the applicable vehicle Service Manual and appropriate Dealer Technical Service Bulletins for additional information regarding system operation and diagnostic/repair procedures.

When this manual refers to a brand name, a number, or a specific tool, you may use an equivalent product in place of the recommended item.

All information, illustrations and specifications in this manual are based on the latest product information at the time of publication approval. General Motors reserves the right to make changes at any time without notice.

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1. Introduction to Alternative Fuels

Alternative Fuel Mandates

Two Federal mandates are currently in place to promote the use of alternate fuel vehicles:

- Clean Air Act Amendments of 1990
- Energy Policy Act of 1992

Clean Air Act

The Clean Air Act was initially established to improve air quality and reduce vehicle emissions. As amended in 1990, the act mandates the use of "clean fuels" in low emission vehicles.

CLEAN FUELS

Clean fuels are described as any fuel meeting low emissions vehicle standards. These include the following:

- Methanol (M85/M100)
- Natural Gas (Compressed/Liquid)
- Electricity
- Reformulated Diesel Fuel
- Ethanol (E85/E100)
- Liquid Petroleum Gas (LPG)
- Reformulated Gasoline

The Clean Air Act applies to specific fleets:

- Light duty vehicles/trucks and heavy duty trucks
- Medium to large fleets in larger metropolitan areas with a centralized fueling location
- Personal fleet vehicle

Emergency, law enforcement, vehicles held for lease or rental to the general public, dealership demos and manufacturer's non-road product evaluation and test vehicles are exempt.

Energy Policy Act

The Energy Policy Act was established in 1992 to reduce the U.S. dependency on petroleum and to provide incentives and mandates for the use of alternative fuels. This policy required the purchase of alternative fuel vehicles for federal fleet use beginning in 1993. State and alternative fuel provider fleets follow in the 1997 model year.

1. Introduction to Alternative Fuels

ALTERNATIVE FUELS

Alternative fuels as described in the Energy Policy Act include the following:

- Natural Gas (Compressed and Liquid)
- Liquid Petroleum Gas (LPG)
- Methanol (M85/M100)
- Ethanol (E85/E100)
- Hydrogen
- Electricity
- Biomass fuels, liquid fuels made from coal

The Energy Policy Act applied to specific fleets:

- Light duty vehicles/trucks
- Large fleets in large metropolitan areas

Lease or rental vehicles, vehicles held for sale by dealers (including demos), manufacturer product evaluation vehicles, law enforcement vehicles, military vehicles, non-road vehicles and vehicles garaged at personal residences at night are exempt.

MANDATED PERCENTAGE OF ALTERNATIVE FUEL VEHICLES PER YEAR

The following chart shows the percentage of alternative fuel vehicles required to be purchased per year according to the Energy Policy Act of 1992 (refer to Figure 1-1).

ALTERNATIVE FUEL FLEET PURCHASE MANDATE
ENERGY POLICY ACT OF 1992
PERCENT OF NEW VEHICLE PURCHASES

YEARS	FEDERAL	STATE	ALTERNATIVE FUEL PROVIDERS
1996	25%	–	–
1997	33%	10%	30%
1998	50%	15%	50%
1999	75%	25%	70%
2000	75%	50%	90%
2001	75%	75%	90%
2002	75%	75%	90%
2003	75%	75%	90%
2004	75%	75%	90%
2005	75%	75%	90%
2006	75%	75%	90%

Figure 1-1, Mandatory Purchase Program

2. Introduction to the Electric S10

Overview

The Chevrolet S10 electric truck is one of the more sophisticated General Motors vehicles. The S-10 uses multiple controllers to monitor and control the propulsion and thermal management systems of the vehicle. Unlike most conventional vehicles, some of the controllers will perform specific tasks with the ignition key in the OFF position.

To aid understanding vehicle operation, this manual divides the truck control system into six separate systems. However, some of the components and controllers are shared by the different systems. A cutaway view of the S10 electric truck is shown in Figure 2-1.

Drive Motor
Battery Pack
Charging
Thermal Control

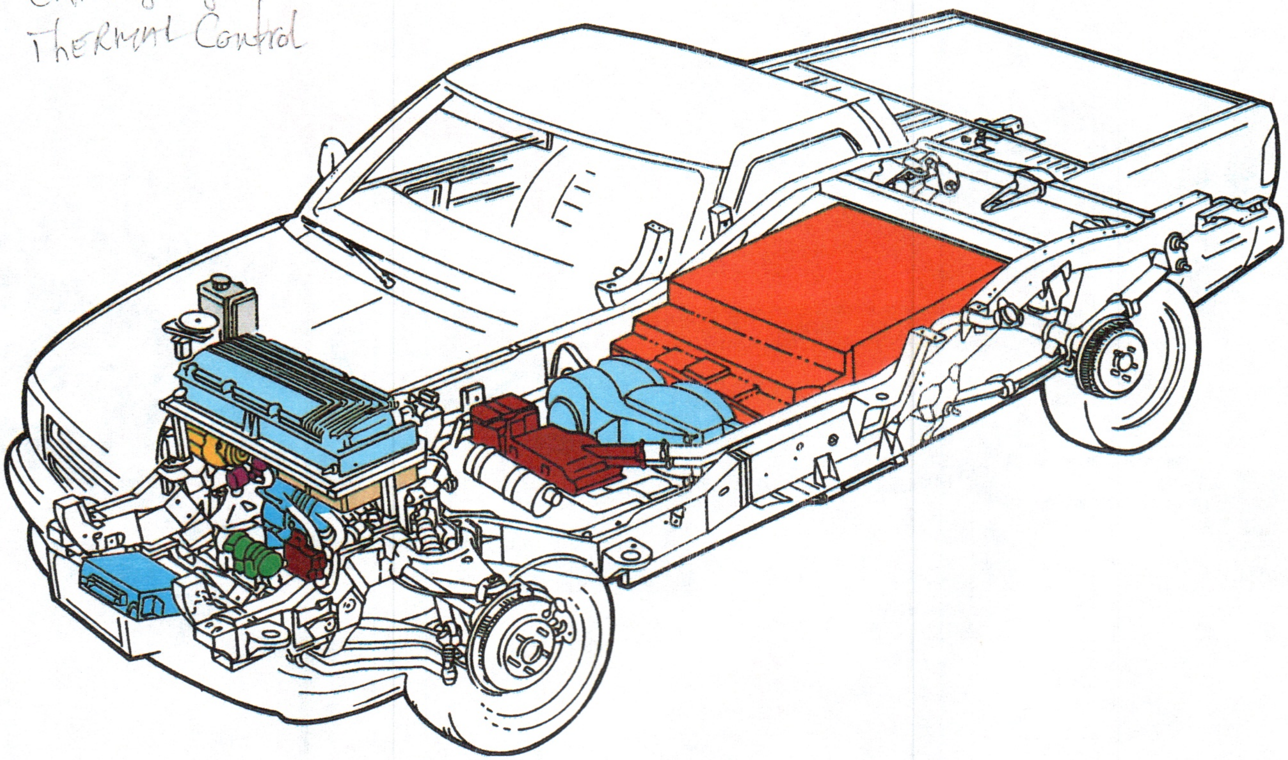
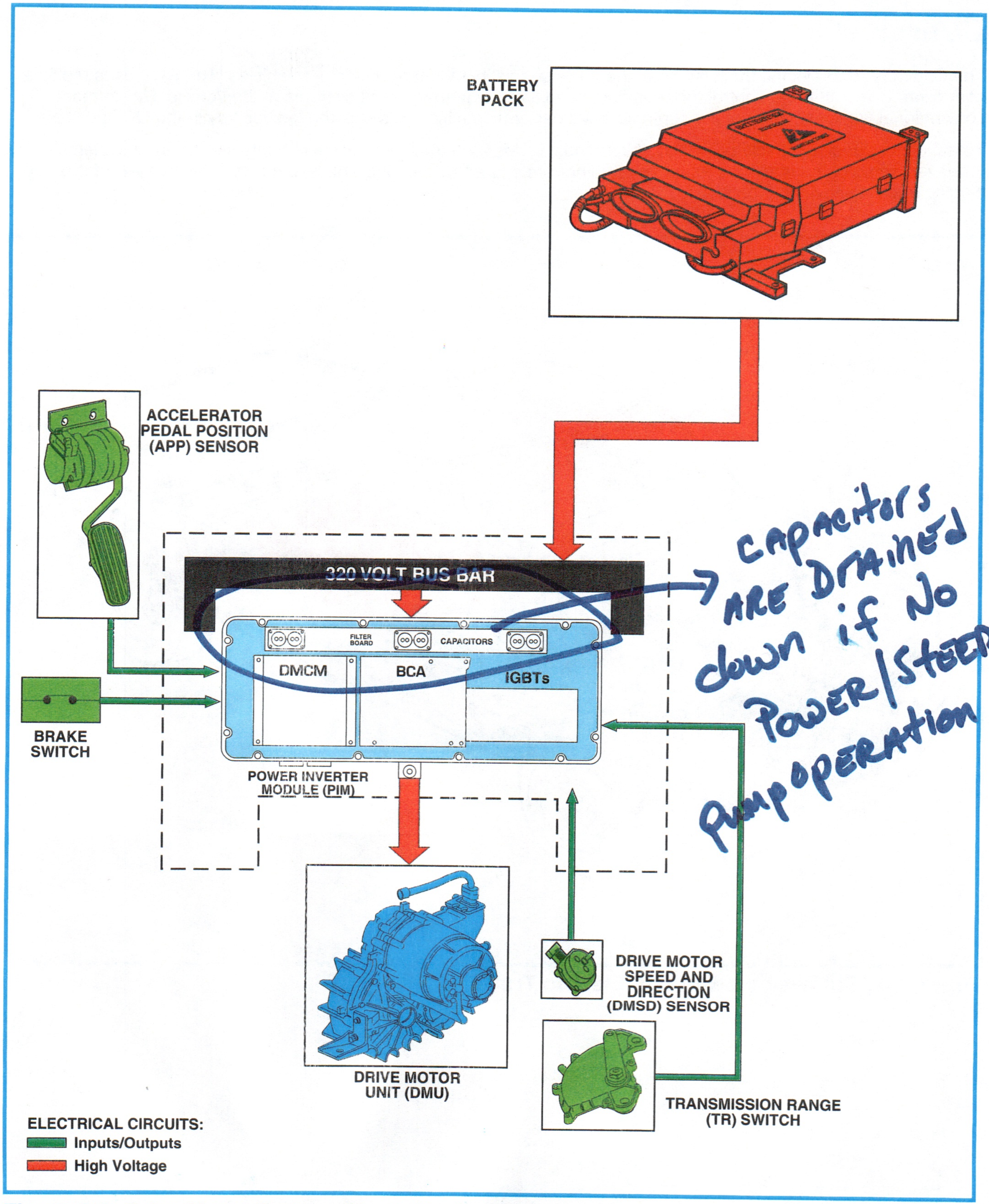


Figure 2-1, Cutaway View of S10 Electric Truck


BATTERY PACK
ACCELERATOR PEDAL POSITION (APP) SENSOR
320 VOLT BUS BAR
FILTER BOARD
CAPACITORS
DMCM
BCA
IGBTs
BRAKE SWITCH
POWER INVERTER MODULE (PIM)
DRIVE MOTOR UNIT (DMU)
DRIVE MOTOR SPEED AND DIRECTION (DMSD) SENSOR
TRANSMISSION RANGE (TR) SWITCH
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

capacitors are Drained down if No Power/Steering pump operation

Figure 2-2, **Drive Motor System Block Diagram**

Drive Motor System

The drive motor system controls the operation of the drive motor. The drive motor is used for vehicle propulsion. Propulsion is based on inputs from the vehicle operator. The drive motor system has the following major components (refer to Figures 2-2 and 2-3):

- Drive Motor Unit (DMU)
- Power Inverter Module (PIM)
- Battery Pack
- Accelerator Pedal Position (APP) Sensor
- Drive Motor Speed and Direction (DMSD) Sensor
- Brake Switch
- Transmission Range (TR) Switch

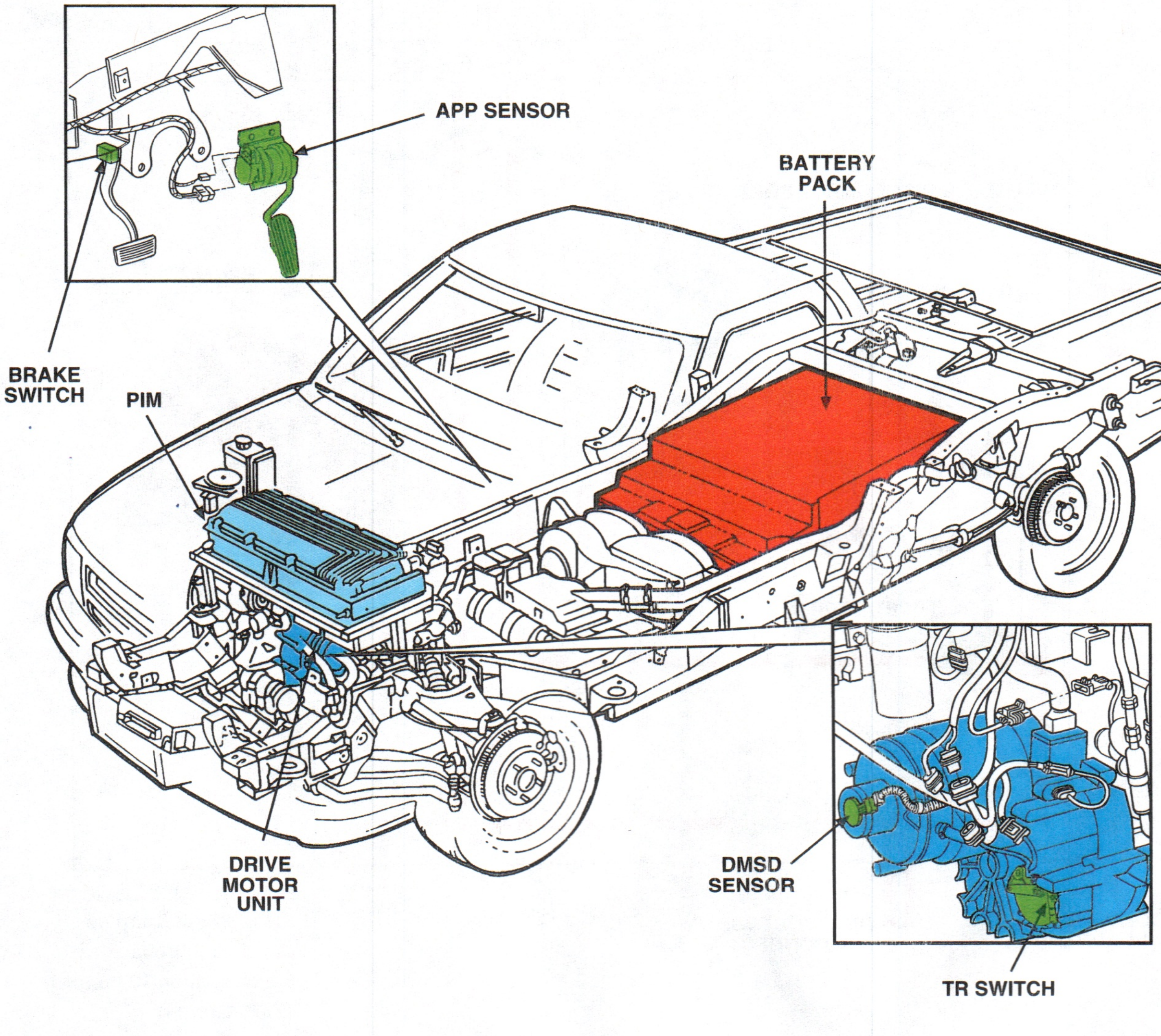

APP SENSOR
BATTERY PACK
BRAKE SWITCH
PIM
DRIVE MOTOR UNIT
DMSD SENSOR
TR SWITCH

Figure 2-3, Drive Motor System Components

The Automatic Disconnect converts the 320 volts from the battery pack into 12 volts for operational voltage. The ground isolation circuit of the High-Voltage Disconnect is not part of the contactor circuits. In 1997, the contactor coil ground side for both contactors is routed through the High-Voltage Disconnect. In 1998, only the negative contactor coil ground side is routed through the High-Voltage Disconnect.

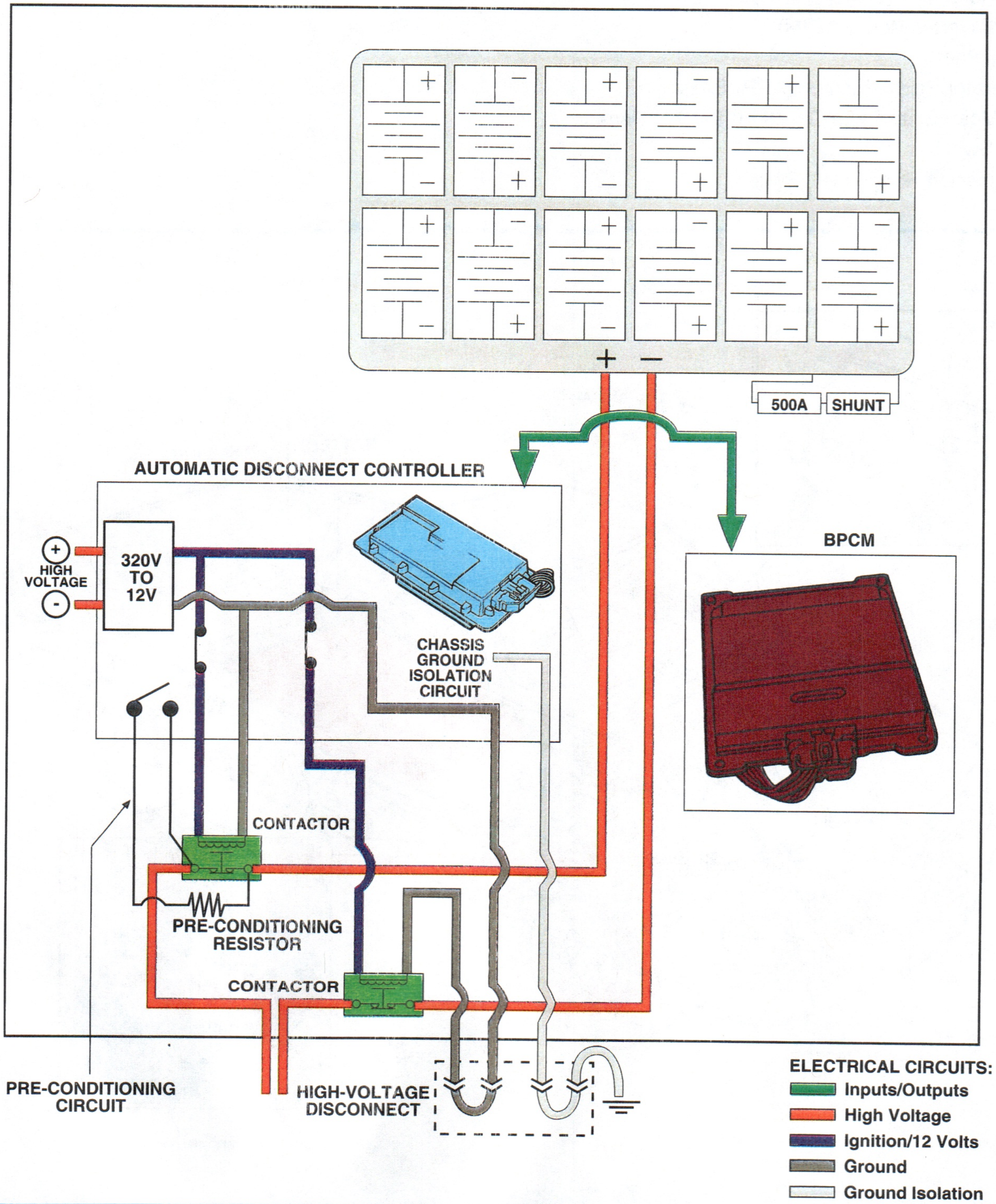

+
−
500A
SHUNT
AUTOMATIC DISCONNECT CONTROLLER
BPCM
+
HIGH VOLTAGE
-
320V TO 12V
CHASSIS GROUND ISOLATION CIRCUIT
CONTACTOR
PRE-CONDITIONING RESISTOR
CONTACTOR
PRE-CONDITIONING CIRCUIT
HIGH-VOLTAGE DISCONNECT
ELECTRICAL CIRCUITS:
Inputs/Outputs
High Voltage
Ignition/12 Volts
Ground
Ground Isolation

Figure 2-4, Battery Pack System Block Diagram

Battery Pack System

The battery pack system monitors the operation of the battery pack. The battery pack provides 320 volts of direct current for vehicle propulsion. The battery pack system has the following components (refer to Figures 2-4 and 2-5):

- 26 Individual Battery Modules
- Automatic Disconnect
- Battery Pack Control Module (BPCM)
- Contactors (2)
- Shunt and Fuse
- Temperature Sensors (6)

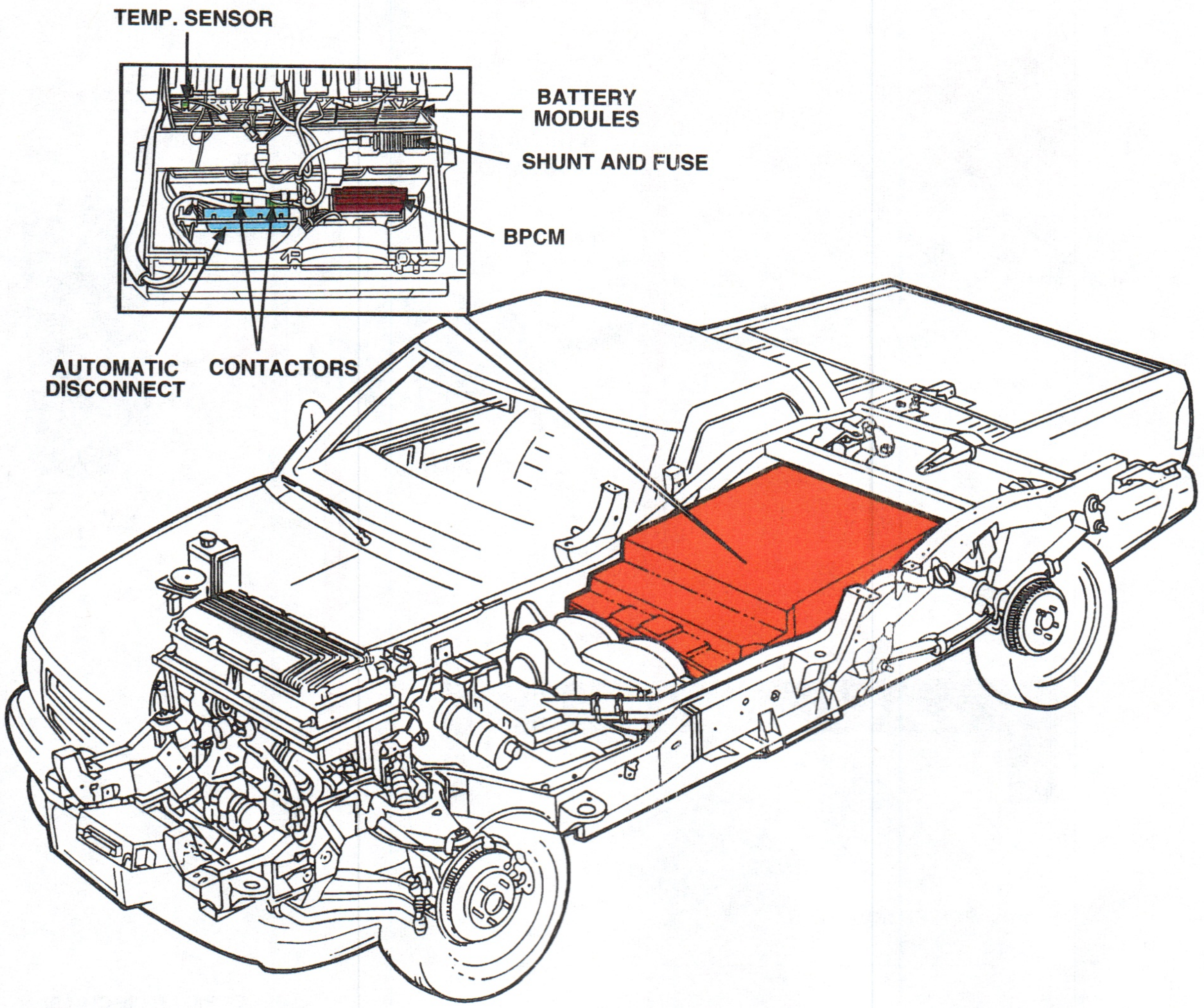

TEMP. SENSOR
BATTERY MODULES
SHUNT AND FUSE
BPCM
AUTOMATIC DISCONNECT
CONTACTORS

Figure 2-5, **Battery Pack System Components**

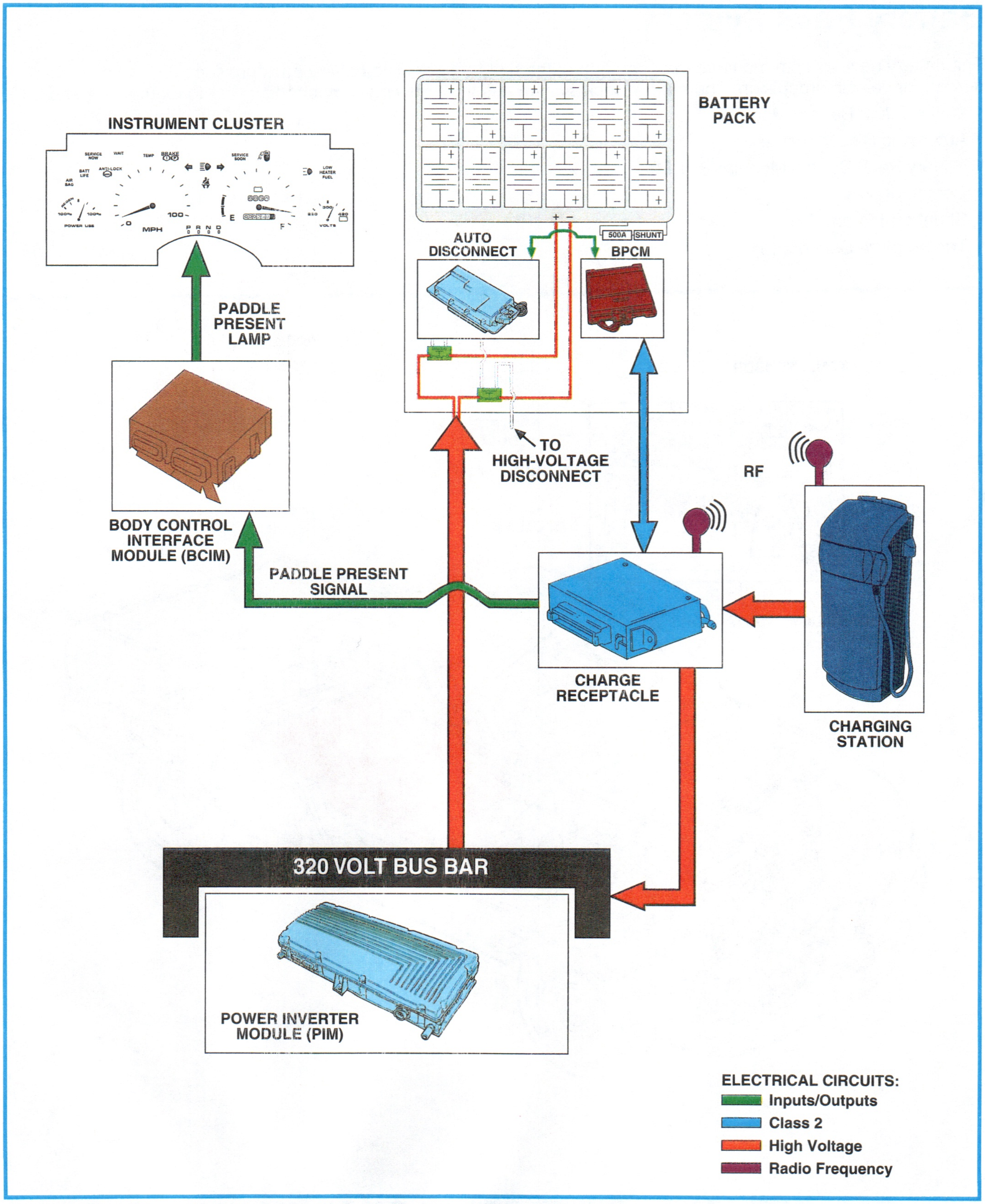

INSTRUMENT CLUSTER
BATTERY PACK
AUTO DISCONNECT
500A SHUNT
BPCM
PADDLE PRESENT LAMP
BODY CONTROL INTERFACE MODULE (BCIM)
TO HIGH-VOLTAGE DISCONNECT
RF
PADDLE PRESENT SIGNAL
CHARGE RECEPTACLE
CHARGING STATION
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟦 Class 2
🟥 High Voltage
🟪 Radio Frequency

Figure 2-6, Charging System Block Diagram

Figure 2-6 on the facing page applies to the 1997 Electric S10.

Notes

In 1998, the Instrument Cluster receives the request to illuminate the Paddle Present Lamp on the Class 2 data line from the Charge Receptacle. A separate Paddle Present signal from the Charge Receptacle is sent to the PIM on a discrete circuit.

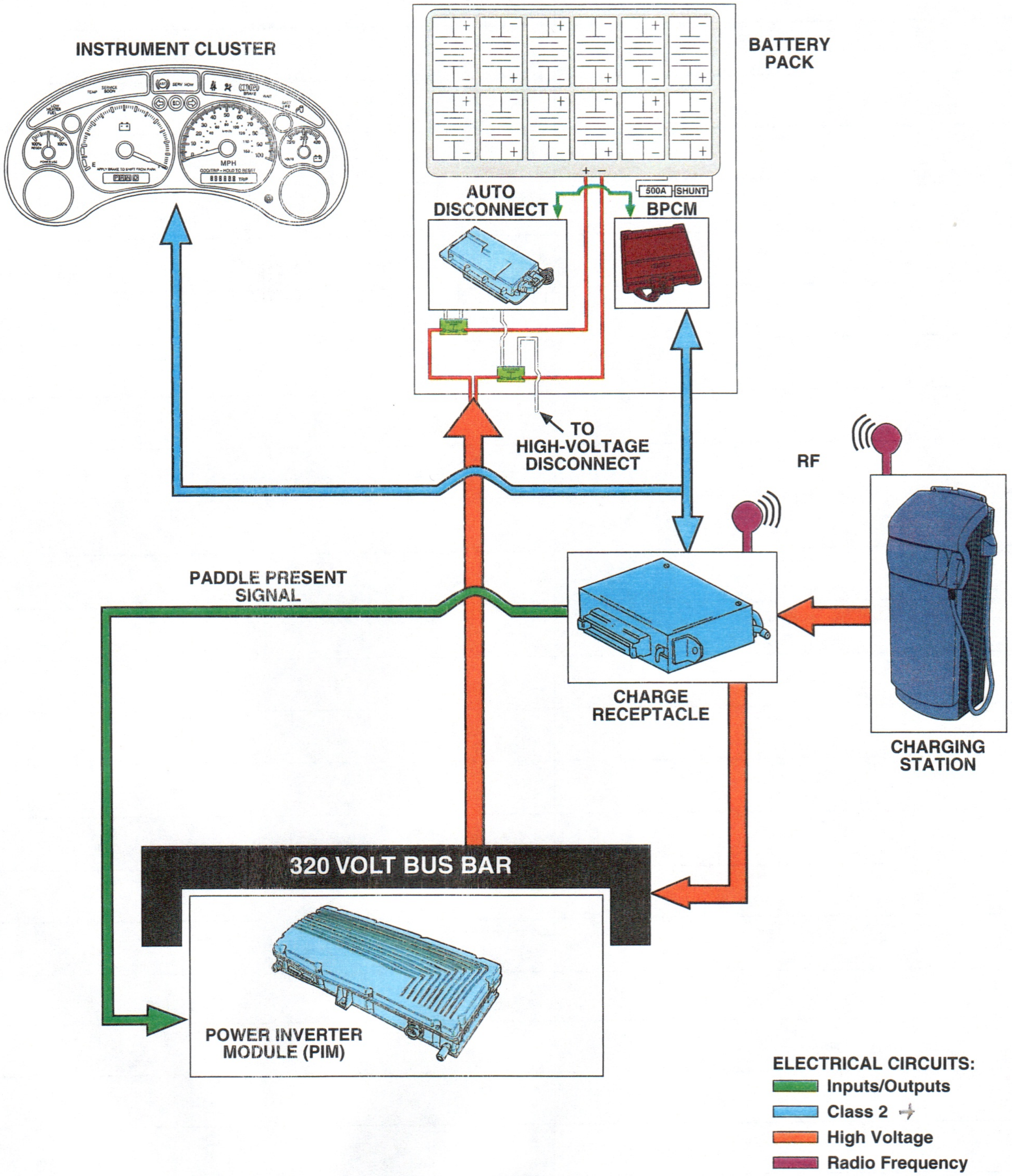

INSTRUMENT CLUSTER
MPH
BATTERY PACK
+ −
500A
SHUNT
AUTO DISCONNECT
BPCM
TO HIGH-VOLTAGE DISCONNECT
RF
PADDLE PRESENT SIGNAL
CHARGE RECEPTACLE
CHARGING STATION
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟦 Class 2
🟧 High Voltage
🟪 Radio Frequency

Figure 2-6a, Charging System Block Diagram

Charging System

The charging system controls the charging rate for the 320-volt battery pack. Charging can occur during both a charging event and regeneration. The charging system has the following components (refer to Figures 2-6 and 2-7):

- Power Inverter Module (PIM)
- Charge Receptacle
- Charging Station
- Battery Pack Control Module (BPCM)
- Body Control Interface Module (BCIM)

Regeneration during Coasting + Braking.

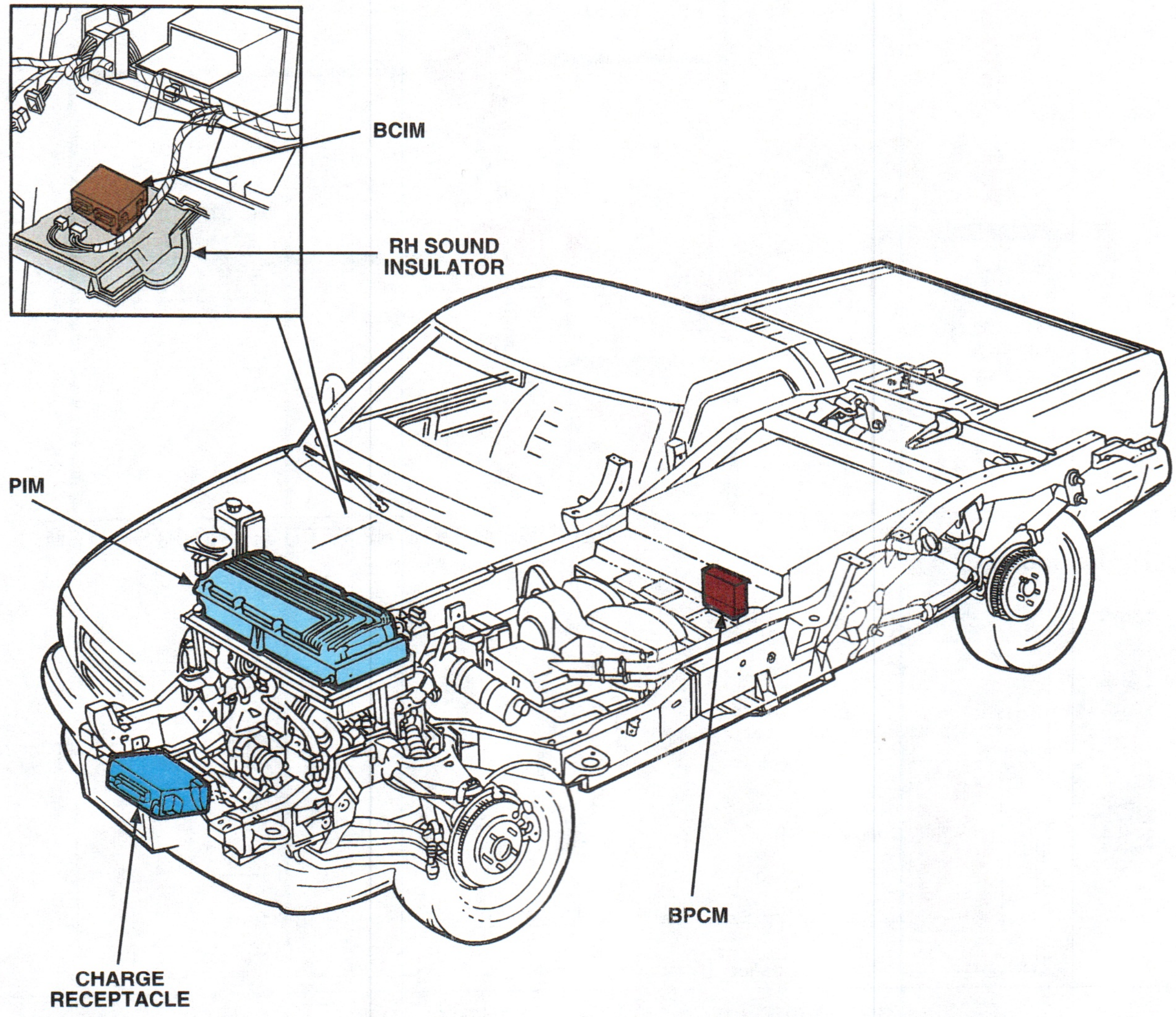


Figure 2-7, **Charging System Components**

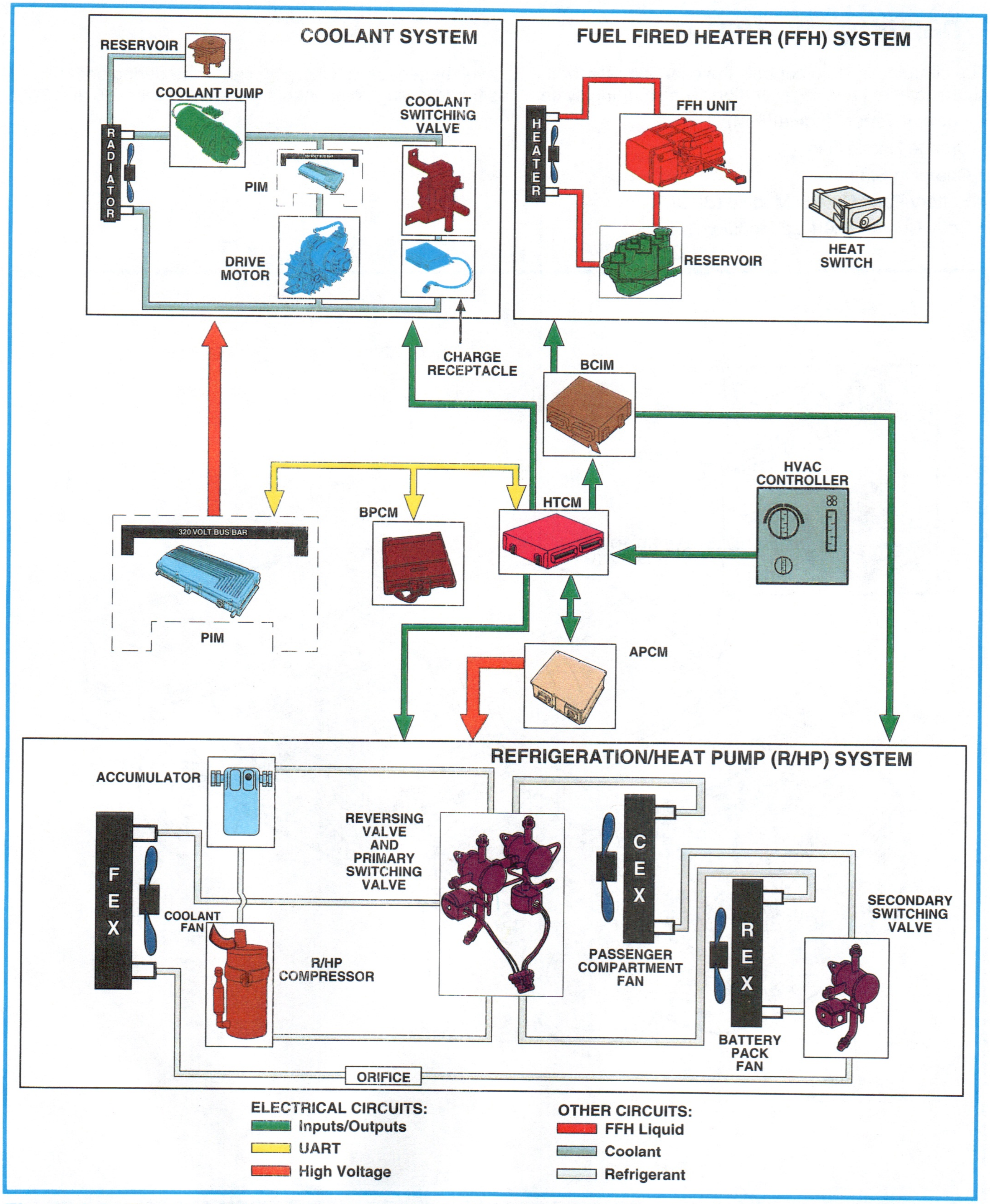

COOLANT SYSTEM
RESERVOIR
COOLANT PUMP
COOLANT SWITCHING VALVE
RADIATOR
320 VOLT BUS BAR
PIM
DRIVE MOTOR
FUEL FIRED HEATER (FFH) SYSTEM
HEATER
FFH UNIT
RESERVOIR
HEAT SWITCH
CHARGE RECEPTACLE
BCIM
HVAC CONTROLLER
HTCM
BPCM
320 VOLT BUS BAR
PIM
APCM
REFRIGERATION/HEAT PUMP (R/HP) SYSTEM
ACCUMULATOR
FEX
COOLANT FAN
REVERSING VALVE AND PRIMARY SWITCHING VALVE
CEX
PASSENGER COMPARTMENT FAN
REX
SECONDARY SWITCHING VALVE
R/HP COMPRESSOR
BATTERY PACK FAN
ORIFICE
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage
OTHER CIRCUITS:
🟥 FFH Liquid
▨ Coolant
☐ Refrigerant

Figure 2-8, Thermal Control System Block Diagram

Thermal Control System

The thermal control system controls the temperature of the passenger compartment (cabin), drive motor unit, Power Inverter Module (PIM), charge receptacle and the battery pack. The thermal control system can provide both cooling and heating to the cabin and the battery pack. It also controls the cooling of the PIM, charge receptacle and drive motor unit. The thermal control system has the following components (refer to Figures 2-8 and 2-9):

- Battery Pack Control Module (BPCM)
- Heating and Thermal Control Module (HTCM)
- Body Control Inferface Module (BCIM)
- Accessory Power Control Module (APCM)
- Power Inverter Module (PIM)
- Heating Ventilation and Air Conditioning (HVAC) Controller
- Blower
- Front EXchanger (FEX) and Rear EXchanger (REX) Fans
- Fuel Fired Heater (FFH) System
- Refrigeration/Heat Pump (R/HP) System
- Coolant System

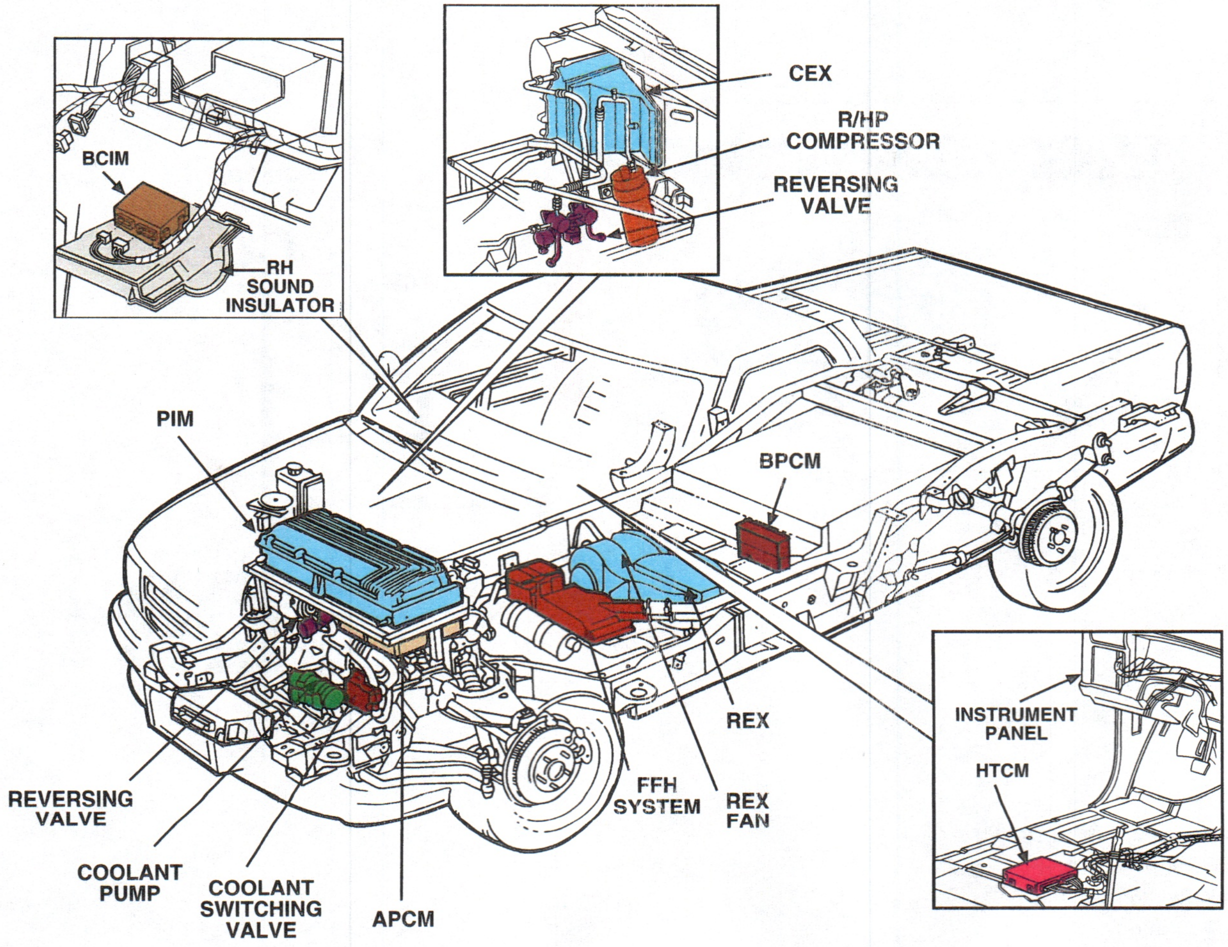
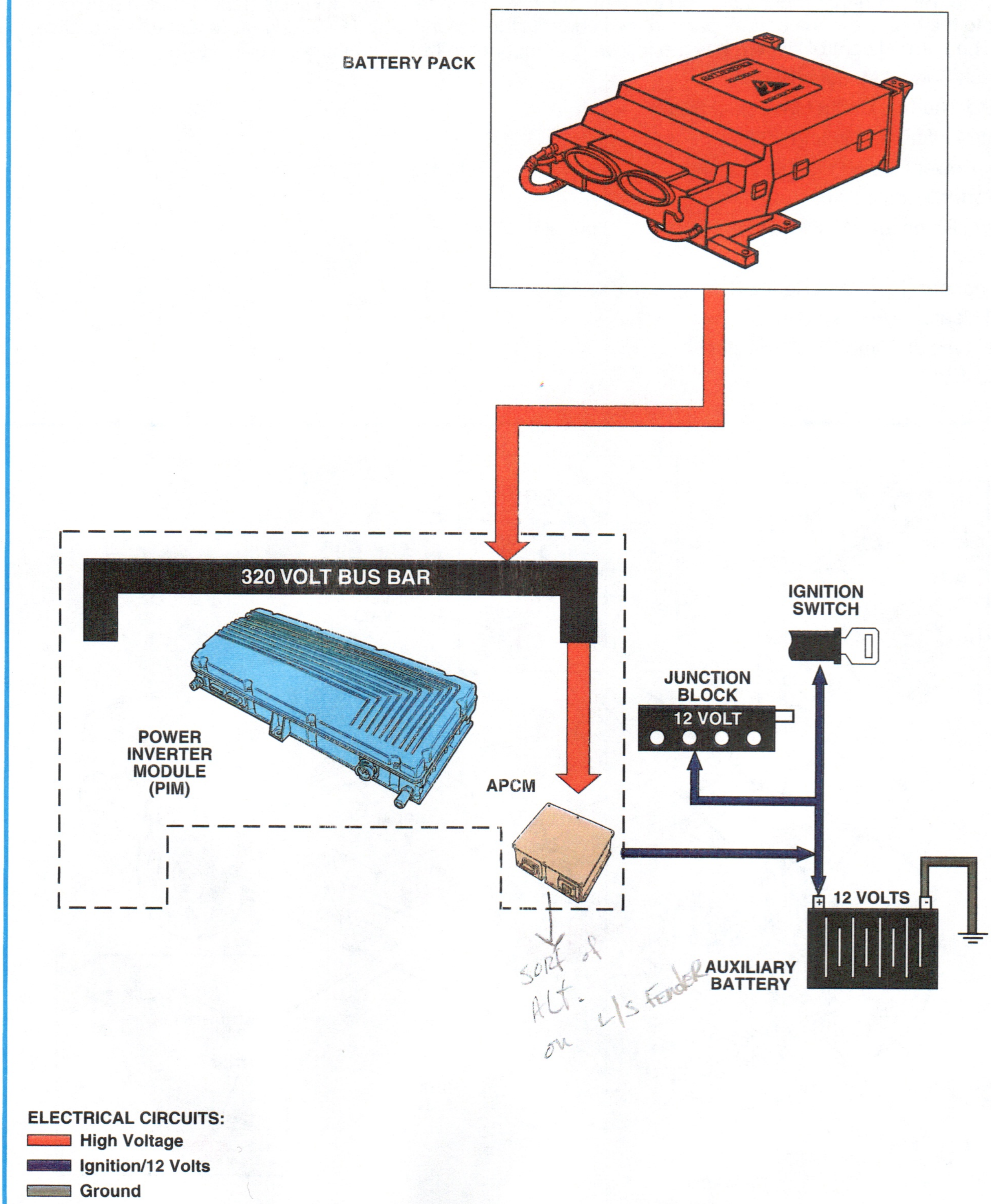

CEX
R/HP COMPRESSOR
REVERSING VALVE
BCIM
RH SOUND INSULATOR
PIM
BPCM
REX
INSTRUMENT PANEL
HTCM
REVERSING VALVE
FFH SYSTEM
REX FAN
COOLANT PUMP
COOLANT SWITCHING VALVE
APCM

Figure 2-9, **Thermal Control System Components**


BATTERY PACK
320 VOLT BUS BAR
IGNITION SWITCH
JUNCTION BLOCK
12 VOLT
POWER INVERTER MODULE (PIM)
APCM
12 VOLTS
+
-
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
🟥 High Voltage
▆ Ignition/12 Volts
▨ Ground

SORT of ALT. on L/S FendeR

Figure 2-10, **Accessory Power System Block Diagram**

Figure 2-10 on the facing page applies to the 1997 Electric S10.

Notes

In 1998, the junction block is replaced with the Underhood Bussed Electrical Center (UBEC). The UBEC is a central location for most fuses and relays. The UBEC also provides power to the Body Bussed Electrical Center (BBEC) and the I/P Fuse Block. The UBEC has a post connected to a maxifuse for aftermarket accessories.

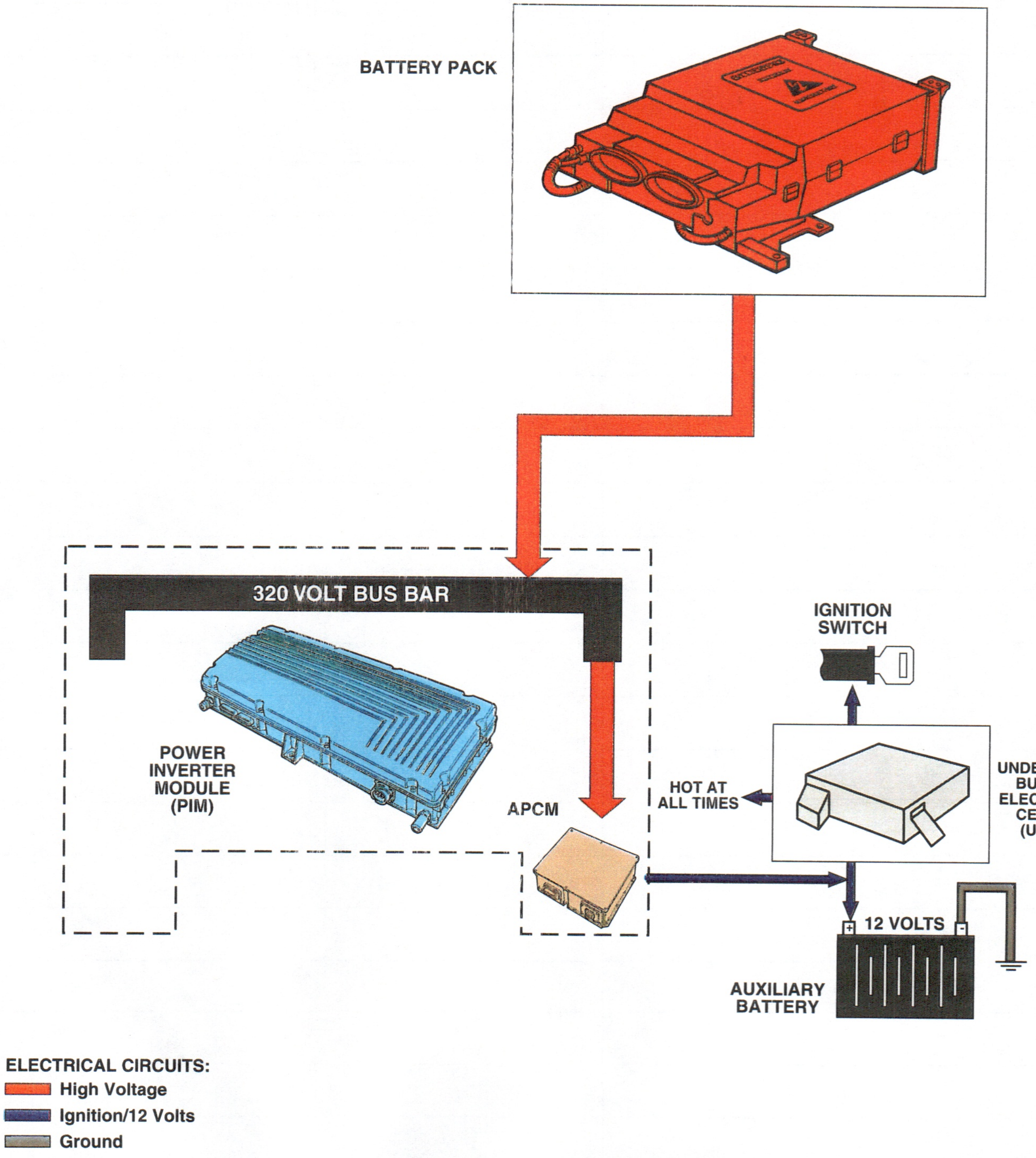

BATTERY PACK
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
HOT AT ALL TIMES
IGNITION SWITCH
UNDERHOOD BUSSED ELECTRICAL CENTER (UBEC)
+
12 VOLTS
-
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
High Voltage
Ignition/12 Volts
Ground

Figure 2-10a, Accessory Power System Block Diagram

Accessory Power System

The accessory power system controls the charging rate for the 12-volt auxiliary (accessory) battery and provides 12-volt system power during propulsion. The accessory power system has the following components (refer to Figures 2-10 and 2-11):

- Accessory Power Control Module (APCM)
- 12-Volt Auxiliary Battery
- Ignition Switch
- Junction Block

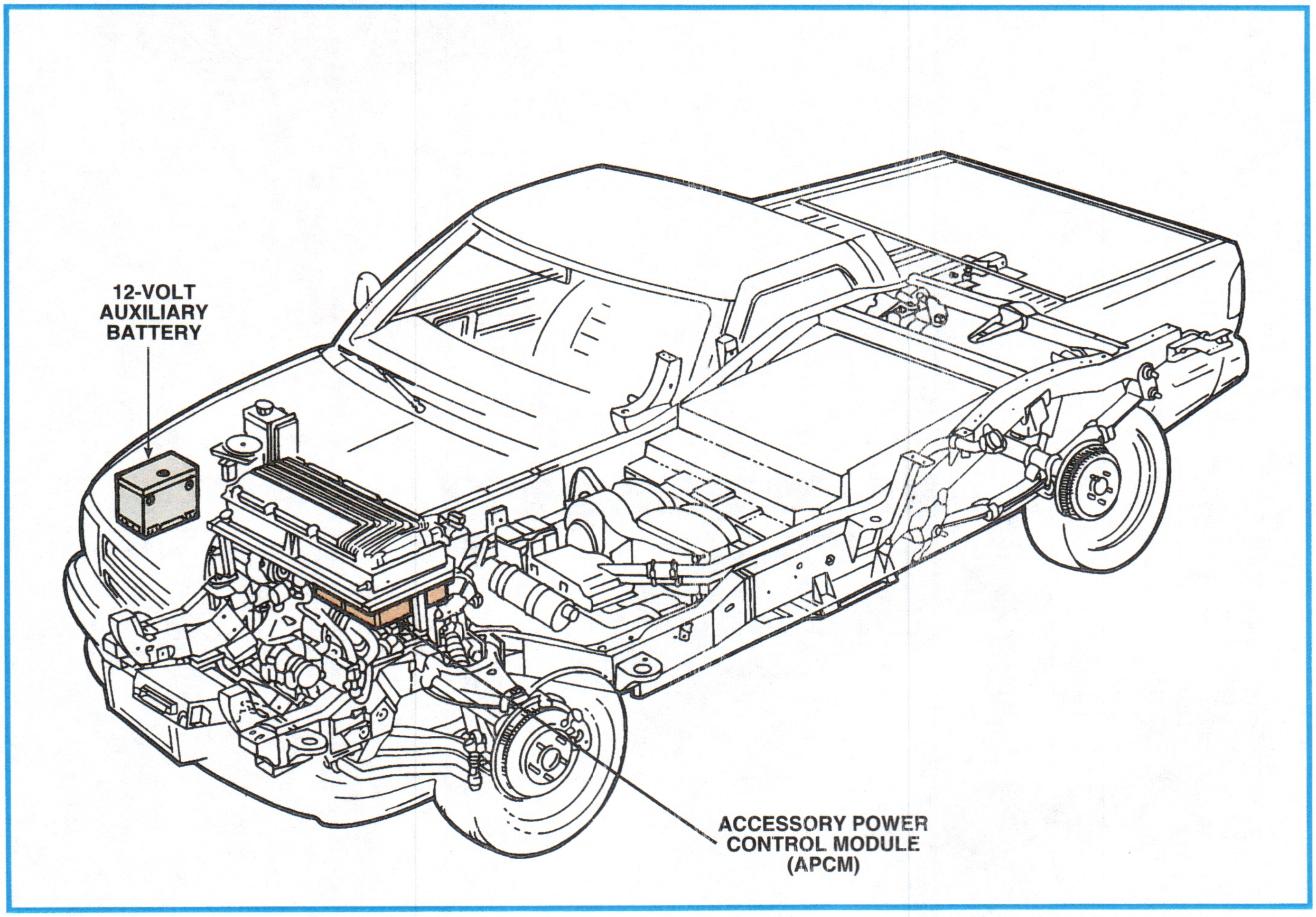

12-VOLT AUXILIARY BATTERY
ACCESSORY POWER CONTROL MODULE (APCM)

Figure 2-11, Accessory Power System Components

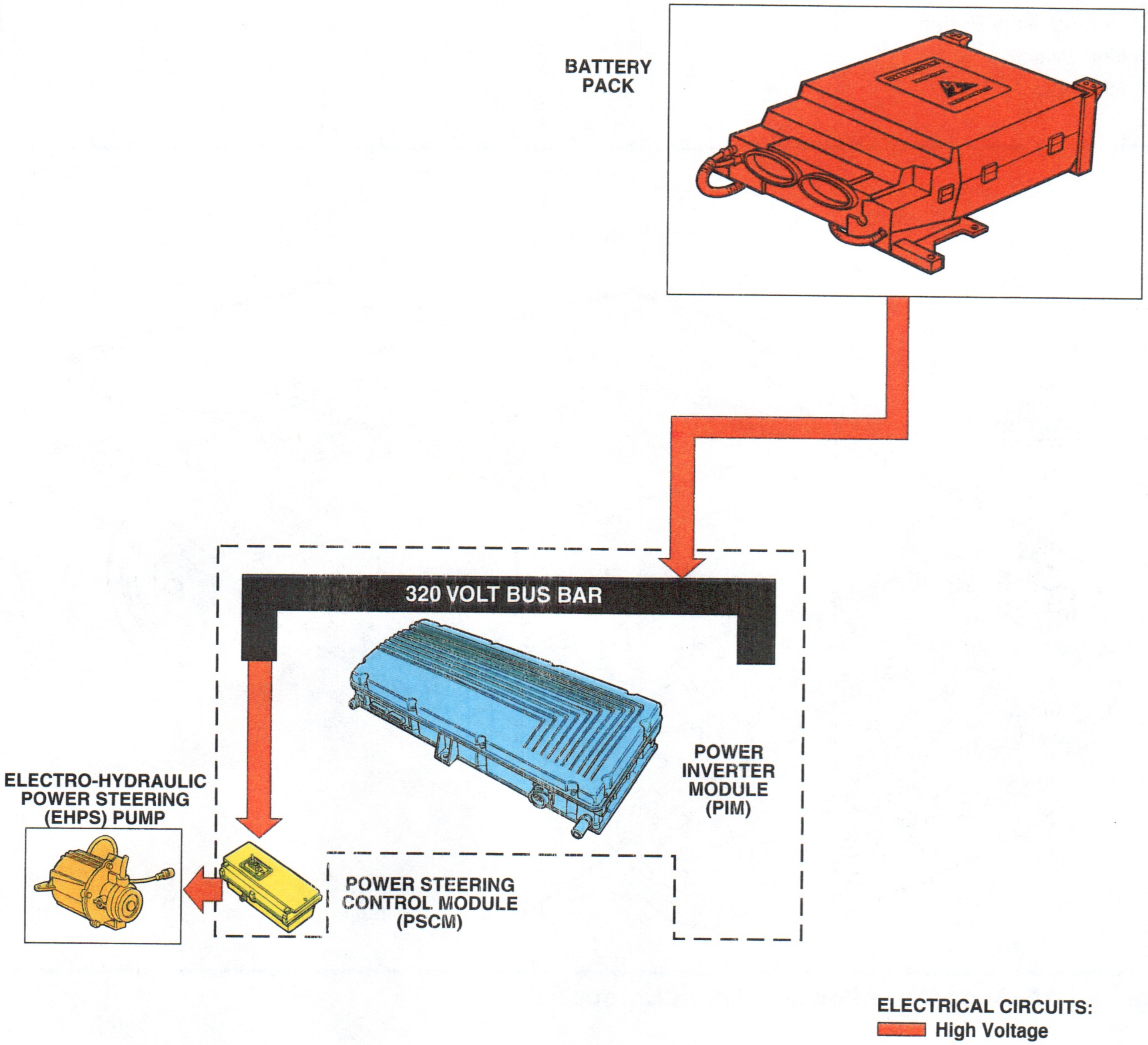

BATTERY PACK
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
ELECTRO-HYDRAULIC POWER STEERING (EHPS) PUMP
POWER STEERING CONTROL MODULE (PSCM)
ELECTRICAL CIRCUITS:
🟥 High Voltage

Figure 2-12, Power Steering System Block Diagram

Power Steering System

The power steering system controls the Electro-Hydraulic Power Steering (EHPS) pump. The power steering system has the following components (refer to Figures 2-12 and 2-13):

- Power Steering Control Module (PSCM)
- Electro-Hydraulic Power Steering (EHPS) Pump

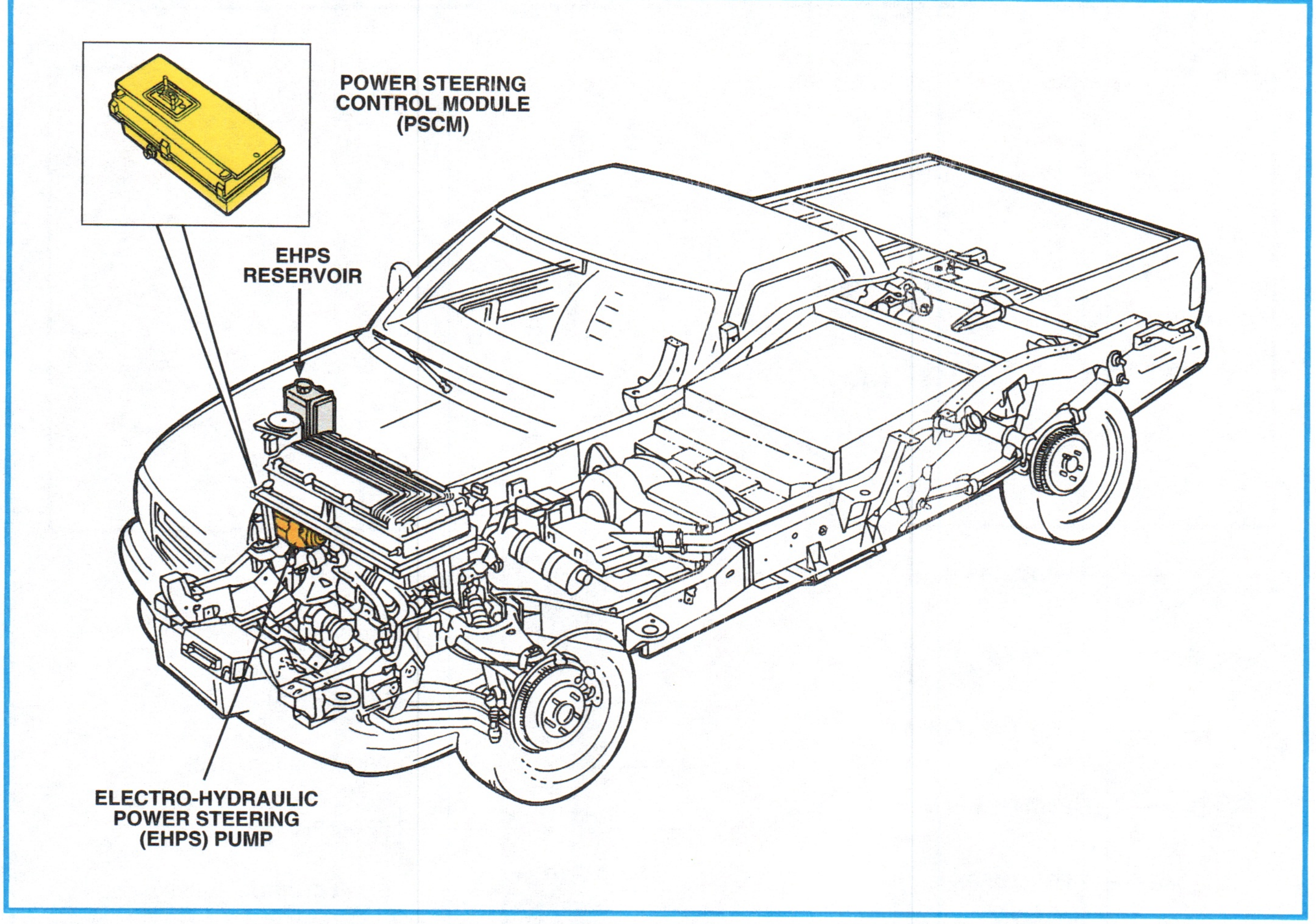

POWER STEERING
CONTROL MODULE
(PSCM)
EHPS
RESERVOIR
ELECTRO-HYDRAULIC
POWER STEERING
(EHPS) PUMP

Figure 2-13, **Power Steering System Components**

Gauges and Lamps

Many of the gauges and lamps located in the instrument cluster are unique to the electric S-10. Refer to Figure 2-14 for an overview of the instrument cluster and the inputs for the various gauges and lamps.

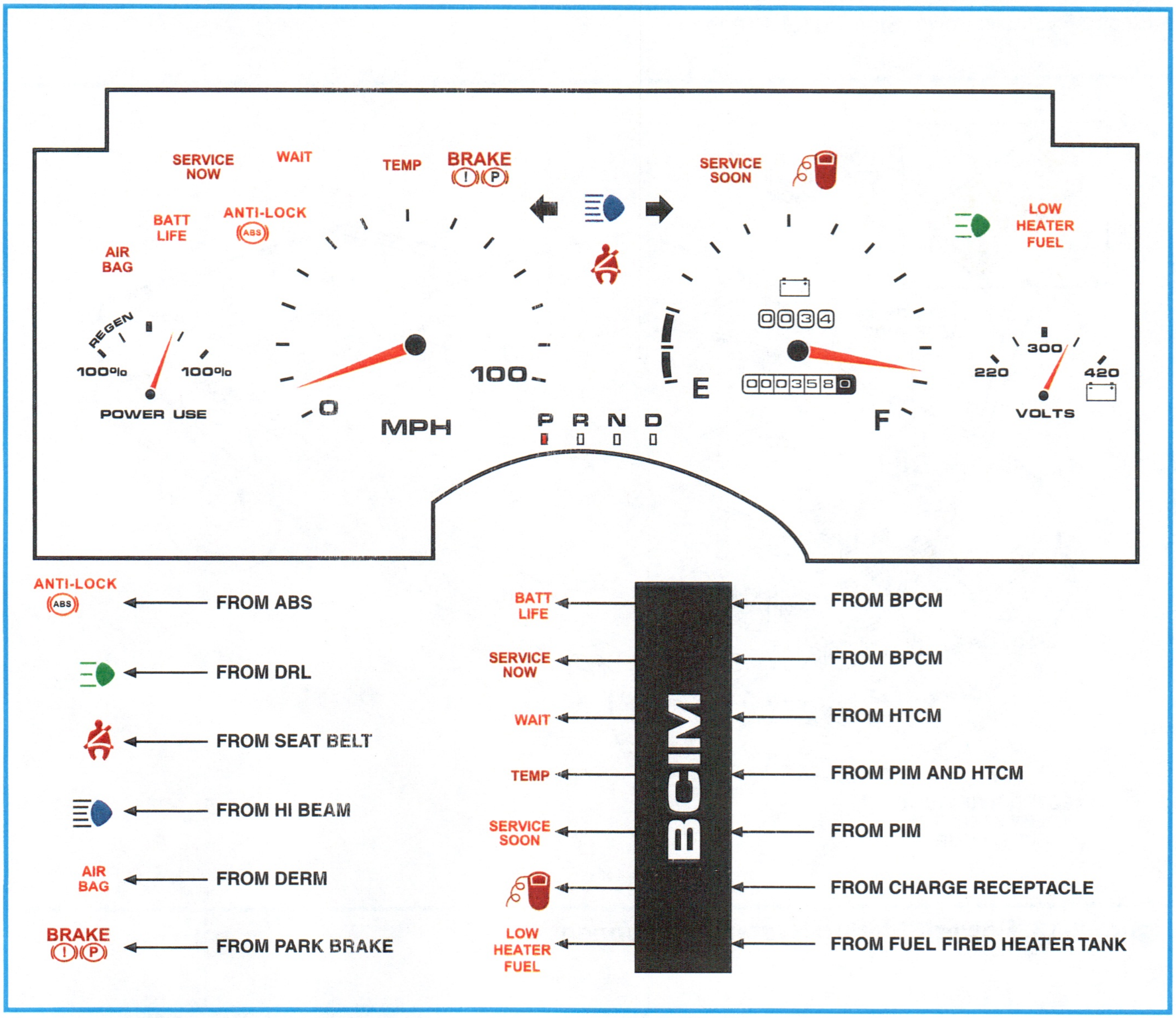

SERVICE NOW
WAIT
TEMP
BRAKE
SERVICE SOON
BATT LIFE
ANTI-LOCK
ABS
AIR BAG
LOW HEATER FUEL
REGEN
100%
100%
POWER USE
0
100
MPH
P R N D
E
F
0034
003580
220
300
420
VOLTS
ANTI-LOCK
ABS
FROM ABS
FROM DRL
FROM SEAT BELT
FROM HI BEAM
AIR BAG
FROM DERM
BRAKE
FROM PARK BRAKE
BATT LIFE
SERVICE NOW
WAIT
TEMP
SERVICE SOON
LOW HEATER FUEL
BCIM
FROM BPCM
FROM BPCM
FROM HTCM
FROM PIM AND HTCM
FROM PIM
FROM CHARGE RECEPTACLE
FROM FUEL FIRED HEATER TANK

Figure 2-14, Gauges and Lamps

Gauges and Lamps (1998)

In 1998, the Instrument Cluster receives most of its information on the Class 2 data line. It also receives some information on discrete circuits from the PIM and BCIM. The BPCM is also the Class 2 translator for any messages on the UART line that must go to the Instrument Cluster.

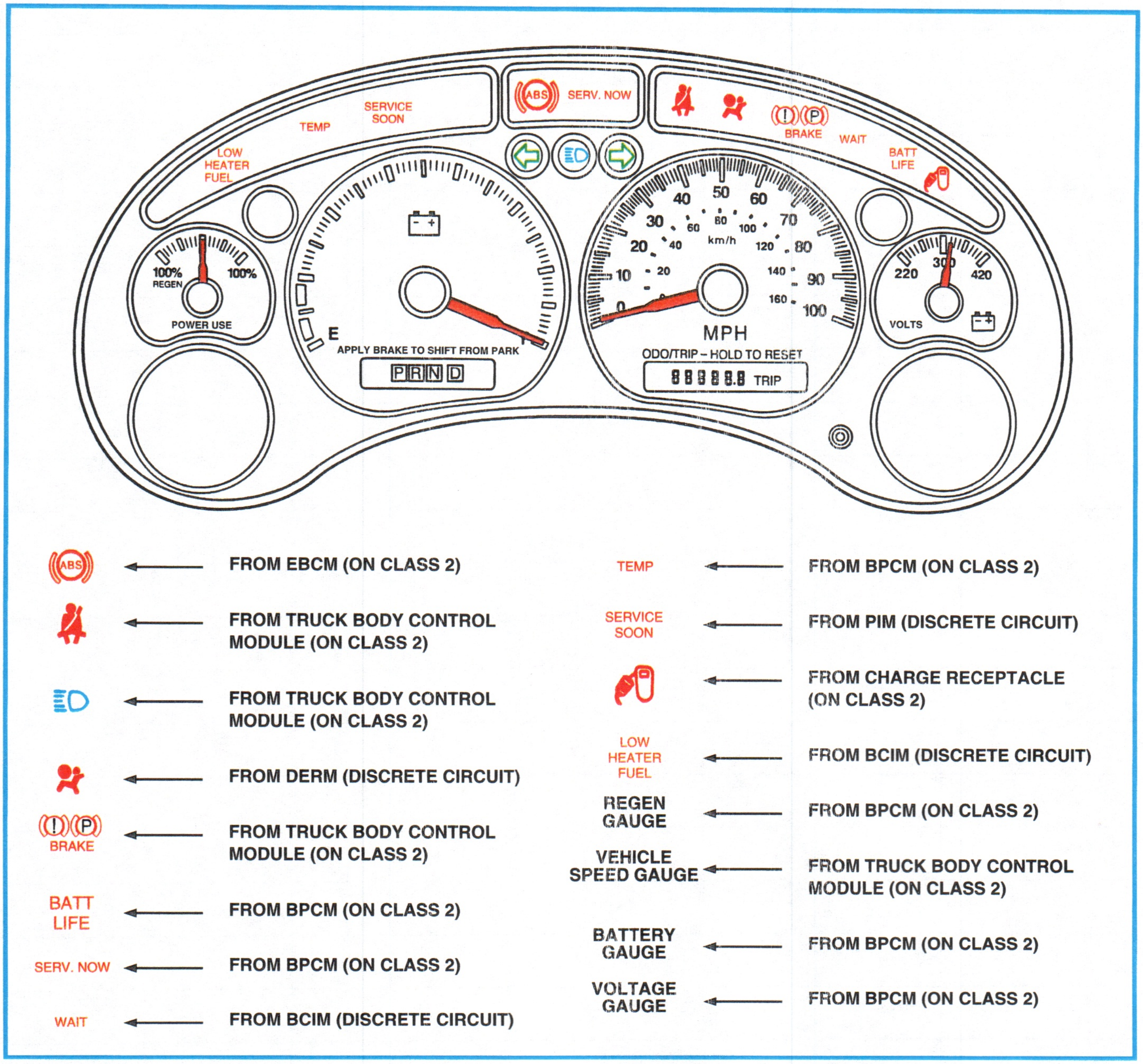

SERVICE SOON
TEMP
LOW HEATER FUEL
ABS
SERV. NOW
BRAKE
WAIT
BATT LIFE
100% REGEN 100%
POWER USE
E
APPLY BRAKE TO SHIFT FROM PARK
PRND
10 20 30 40 50 60 70 80 90 100
20 40 60 80 100 120 140 160
km/h
MPH
ODO/TRIP – HOLD TO RESET
TRIP
220 300 420
VOLTS
ABS ← FROM EBCM (ON CLASS 2)
← FROM TRUCK BODY CONTROL MODULE (ON CLASS 2)
← FROM TRUCK BODY CONTROL MODULE (ON CLASS 2)
← FROM DERM (DISCRETE CIRCUIT)
BRAKE ← FROM TRUCK BODY CONTROL MODULE (ON CLASS 2)
BATT LIFE ← FROM BPCM (ON CLASS 2)
SERV. NOW ← FROM BPCM (ON CLASS 2)
WAIT ← FROM BCIM (DISCRETE CIRCUIT)
TEMP ← FROM BPCM (ON CLASS 2)
SERVICE SOON ← FROM PIM (DISCRETE CIRCUIT)
← FROM CHARGE RECEPTACLE (ON CLASS 2)
LOW HEATER FUEL ← FROM BCIM (DISCRETE CIRCUIT)
REGEN GAUGE ← FROM BPCM (ON CLASS 2)
VEHICLE SPEED GAUGE ← FROM TRUCK BODY CONTROL MODULE (ON CLASS 2)
BATTERY GAUGE ← FROM BPCM (ON CLASS 2)
VOLTAGE GAUGE ← FROM BPCM (ON CLASS 2)

Figure 2-15, Gauges and Lamps (1998)

Notes

3. Drive Motor System Operation

Overview

The drive motor system is responsible for providing forward and reverse propulsion of the truck. To provide propulsion, the drive motor system requires two electrical systems. The 12-volt system is used to power control systems and accessories. The 320-volt system is used to power the drive motor unit, Refrigeration/Heat Pump (R/HP) compressor and Electro-Hydraulic Power Steering (EHPS) pump.

The drive motor system is composed of various control modules, inputs and the drive motor unit. The drive motor is an AC induction motor. It has a rotor and field windings. Connected to the drive motor is the drive motor gear box. The gear box contains a reduction gear set and a differential gear set (see Figure 3-1).

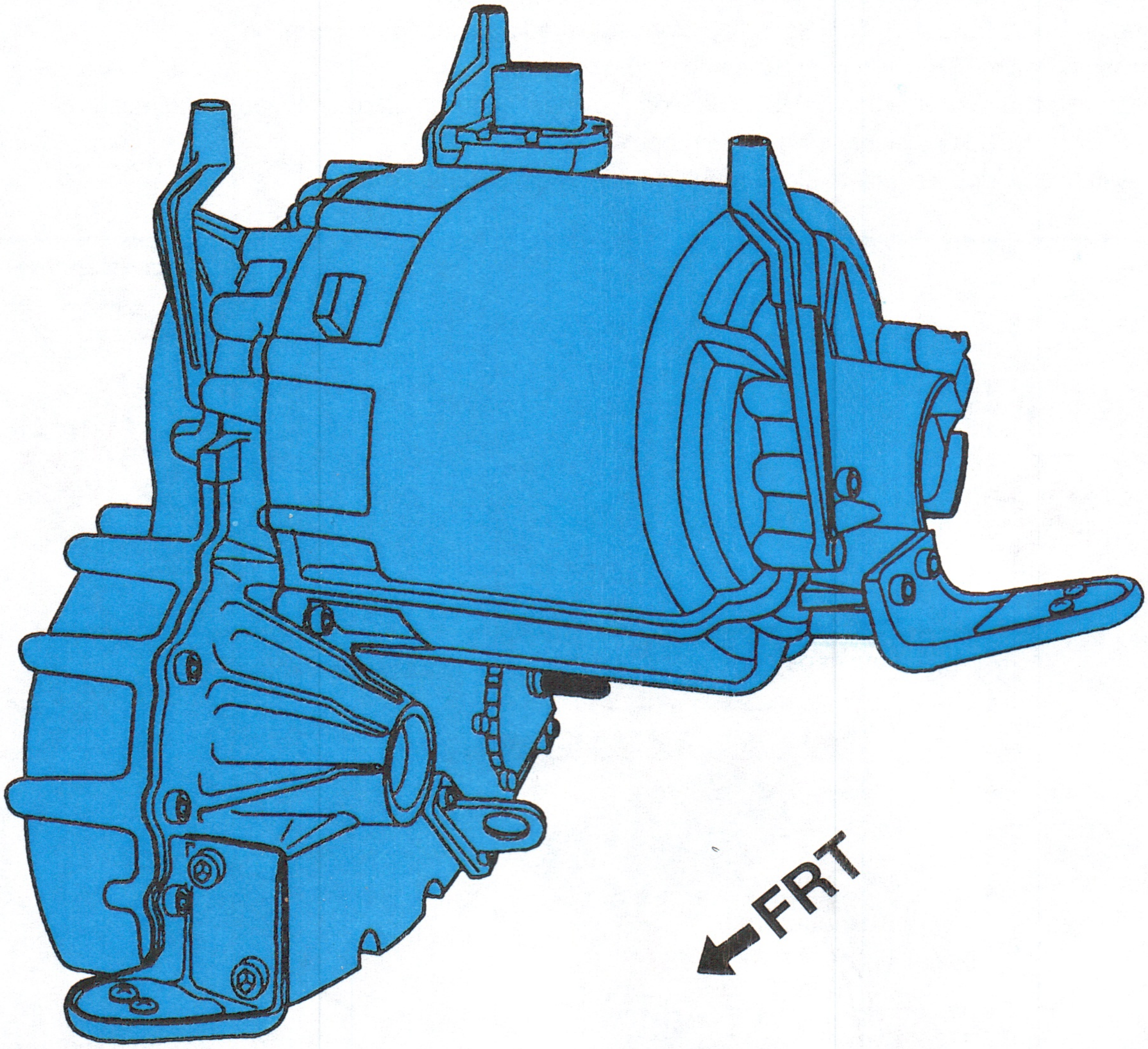


Figure 3-1, **Drive Motor Unit**

Overview – Continued

The following are the Control Modules used for drive motor operation (refer to Figure 3-2):

- Power Inverter Module (PIM)
- Battery Pack Control Module (BPCM)
- Automatic Disconnect
- Body Control Interface Module (BCIM)
- Heating and Thermal Control Module (HTCM)

The PIM is the primary controller for the drive motor. The PIM processes inputs from both components and systems to determine drive motor control. The following are the components used for drive motor operation (refer to Figure 3-3):

- Run 2 Relay: enables propulsion No Relay - No Go
- Instrument Cluster: used to communicate with the vehicle operator and technician
- 320-Volt Battery Pack and Contactors: provides power for propulsion
- Acceleration Pedal Position (APP) Sensor: provides desired speed and acceleration
- Transmission Range (TR) Switch: provides desired direction
- Drive Motor Speed and Direction (DMSD) Sensor: provides feedback on rotor speed and direction
- Ignition Switch: provides a signal for desired propulsion
- Brake Switch: provides a signal to stop propulsion and begin regeneration

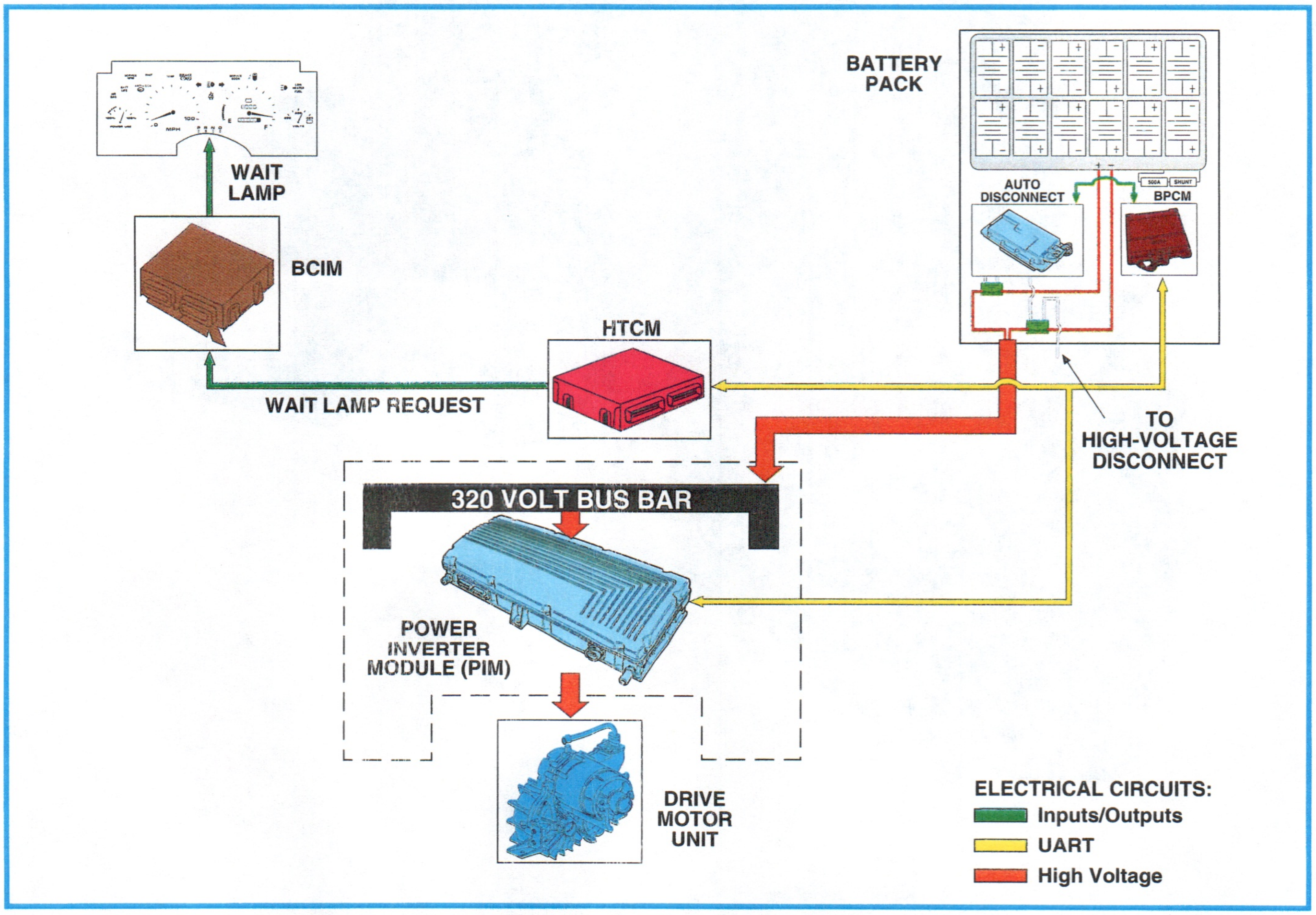

WAIT LAMP
BCIM
BATTERY PACK
AUTO DISCONNECT
500A SHUNT
BPCM
HTCM
WAIT LAMP REQUEST
TO HIGH-VOLTAGE DISCONNECT
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
DRIVE MOTOR UNIT
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage

Figure 3-2, **Drive Motor System Block Diagram**

Notes

Overview – Continued

Figure 3-3 on the facing page applies to the 1997 Electric S10.

In 1998, the switch side of the RUN 2 Relay is Hot At All Times.

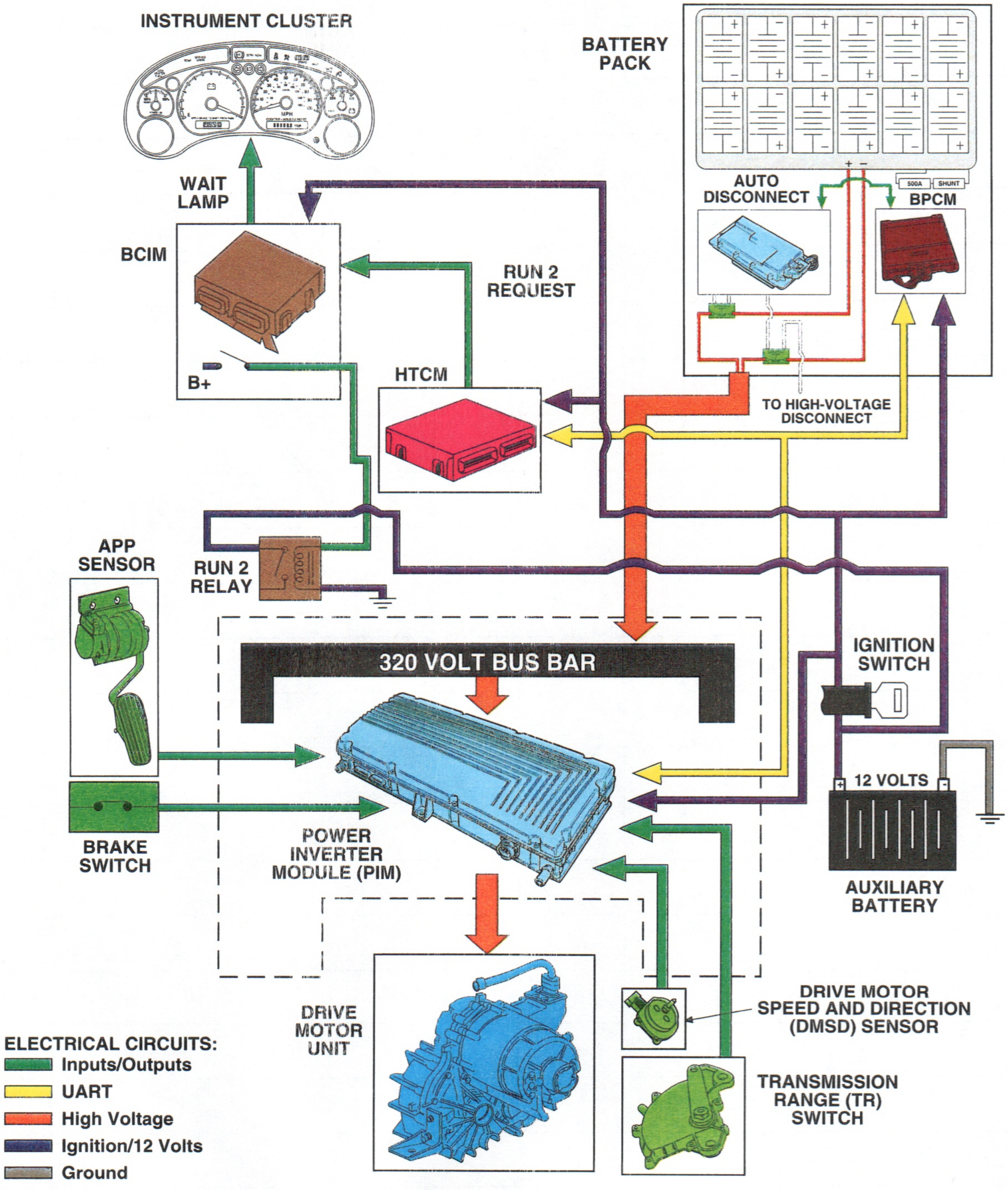

INSTRUMENT CLUSTER
BATTERY PACK
WAIT LAMP
AUTO DISCONNECT
500A
SHUNT
BPCM
BCIM
RUN 2 REQUEST
B+
HTCM
TO HIGH-VOLTAGE DISCONNECT
APP SENSOR
RUN 2 RELAY
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
AUXILIARY BATTERY
BRAKE SWITCH
POWER INVERTER MODULE (PIM)
DRIVE MOTOR UNIT
DRIVE MOTOR SPEED AND DIRECTION (DMSD) SENSOR
TRANSMISSION RANGE (TR) SWITCH
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage
🟦 Ignition/12 Volts
▨ Ground

Figure 3-3a, Drive Motor System

The ignition switch provides the initial “wake-up” for the drive motor system control modules. When the control modules receive the ignition “wake-up,” they begin testing. Upon successful completion of testing, the BPCM and PIM signal the HTCM that propulsion can be enabled. The HTCM provides a RUN 2 request signal to the BCIM, and the BCIM provides the ground to the RUN 2 relay coil. The RUN 2 relay coil provides a 12-volt signal to various control modules to enable propulsion.

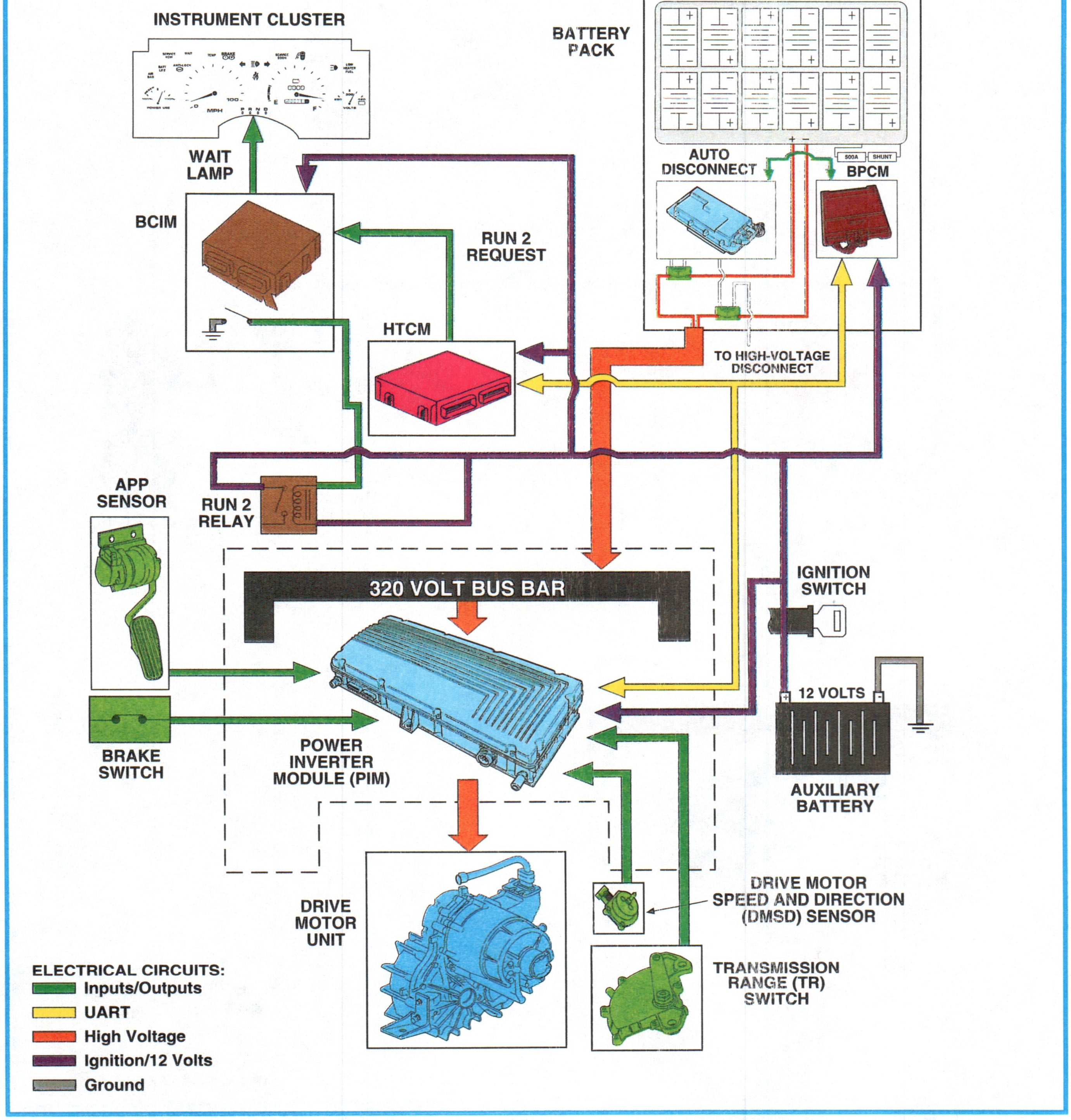

INSTRUMENT CLUSTER
BATTERY PACK
WAIT LAMP
AUTO DISCONNECT
500A
SHUNT
BPCM
BCIM
RUN 2 REQUEST
HTCM
TO HIGH-VOLTAGE DISCONNECT
APP SENSOR
RUN 2 RELAY
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
BRAKE SWITCH
POWER INVERTER MODULE (PIM)
AUXILIARY BATTERY
DRIVE MOTOR SPEED AND DIRECTION (DMSD) SENSOR
DRIVE MOTOR UNIT
TRANSMISSION RANGE (TR) SWITCH
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage
🟪 Ignition/12 Volts
⬜ Ground

Figure 3-3, Drive Motor System

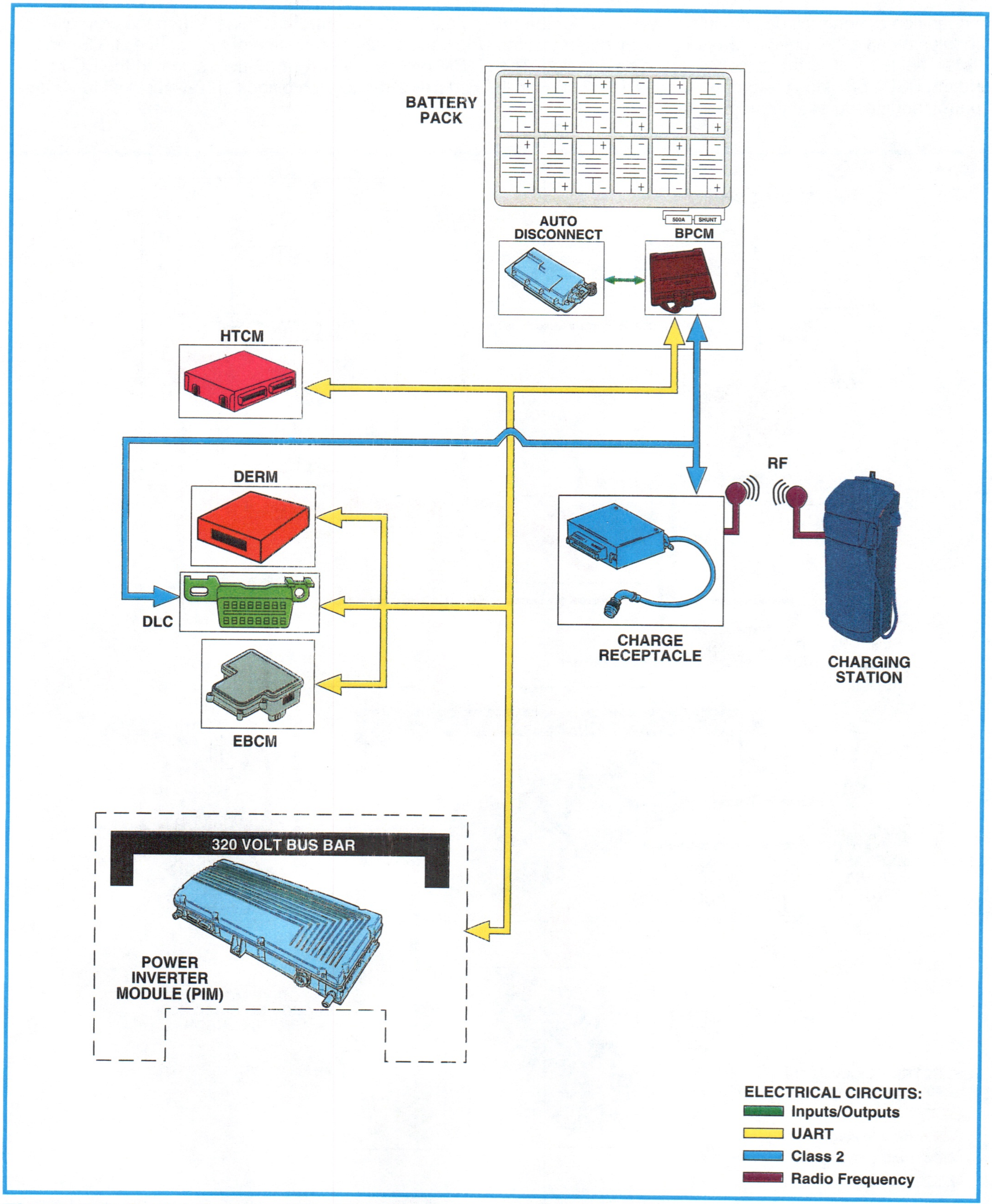

BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
HTCM
DERM
DLC
EBCM
RF
CHARGE RECEPTACLE
CHARGING STATION
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟦 Class 2
🟥 Radio Frequency

Figure 3-4, Serial Communications Block Diagram

Serial Communications (1997)

The 1997 electric truck uses three types of serial communication. These include:

- Universal Asynchronous Receive and Transmit (UART)
- Class 2
- Radio Frequency (RF)

The UART data line provides communication between the following components (refer to Figure 3-4):

- Power Inverter Module (PIM)
- Heating and Thermal Control Module (HTCM)
- Battery Pack Control Module (BPCM)
- Data Link Connector (DLC)
- Diagnostic Energy Reserve Module (DERM)
- Electronic Brake Control Module (EBCM)

The Class 2 data line provides communication between the following components:

- Battery Pack Control Module (BPCM)
- Charge Receptacle
- Data Link Connector (DLC)

Radio Frequency provides communication between the charge receptacle and the charging station. The charge receptacle converts the RF signal to class 2 data to provide a communication link between the BPCM and the charging station.

The serial communication circuits allow the various control modules to communicate using serial data. Serial data is a series of rapidly changing voltage signals pulsed from high voltage to low voltage (refer to Figure 3-5 on page 3-5). These voltage signals are typically 5, 7 or 12 volts (high) to 0 volts (low) and are transmitted through a wire often referred to as the Serial Data Line.

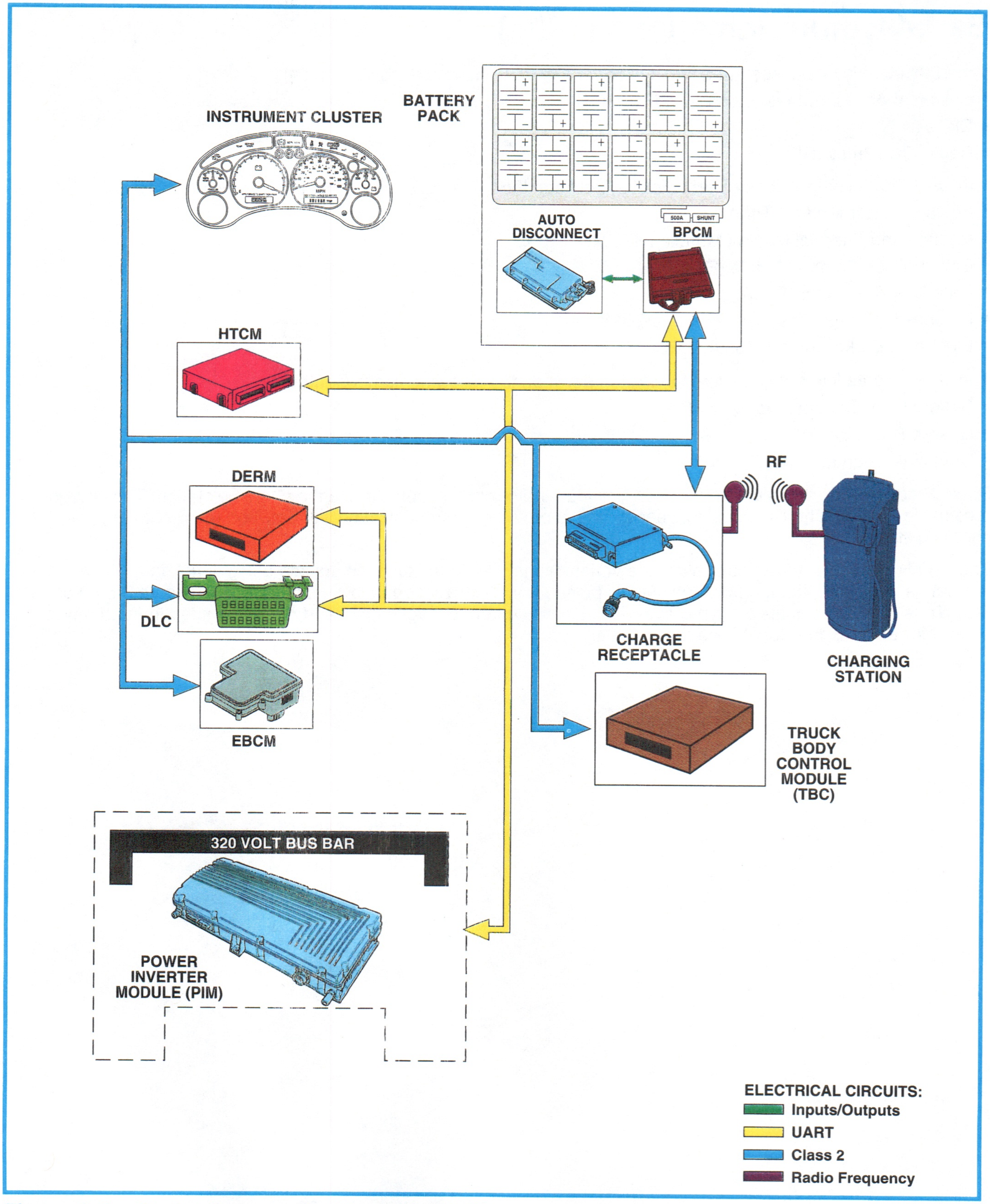

BATTERY PACK
INSTRUMENT CLUSTER
500A
SHUNT
AUTO DISCONNECT
BPCM
HTCM
RF
DERM
DLC
EBCM
CHARGE RECEPTACLE
CHARGING STATION
TRUCK BODY CONTROL MODULE (TBC)
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟦 Class 2
🟪 Radio Frequency

Figure 3-4a, Serial Communications Block Diagram

Serial Communications (1998)

The 1998 electric truck uses three types of serial communication. These include:

- Universal Asynchronous Receive and Transmit (UART)
- Class 2
- Radio Frequency (RF)

The UART data line provides communication between the following components (refer to Figure 3-4a):

- Power Inverter Module (PIM)
- Heating and Thermal Control Module (HTCM)
- Battery Pack Control Module (BPCM)
- Data Link Connector (DLC)
- Diagnostic Energy Reserve Module (DERM)

The Class 2 data line provides communication between the following components:

- Battery Pack Control Module (BPCM)
- Charge Receptacle
- Data Link Connector (DLC)
- Truck Body Control module (TBC)
- Electronic Brake Control Module (EBCM)
- Instrument Cluster

Radio Frequency provides communication between the charge receptacle and the charging station. The charge receptacle converts the RF signal to class 2 data to provide a communication link between the BPCM and the charging station.

The serial communication circuits allow the various control modules to communicate using serial data. Serial data is a series of rapidly changing voltage signals pulsed from high voltage to low voltage (refer to Figure 3-5). These voltage signals are typically 5, 7 or 12 volts (high) to 0 volts (low) and are transmitted through a wire often referred to as the Serial Data Line.

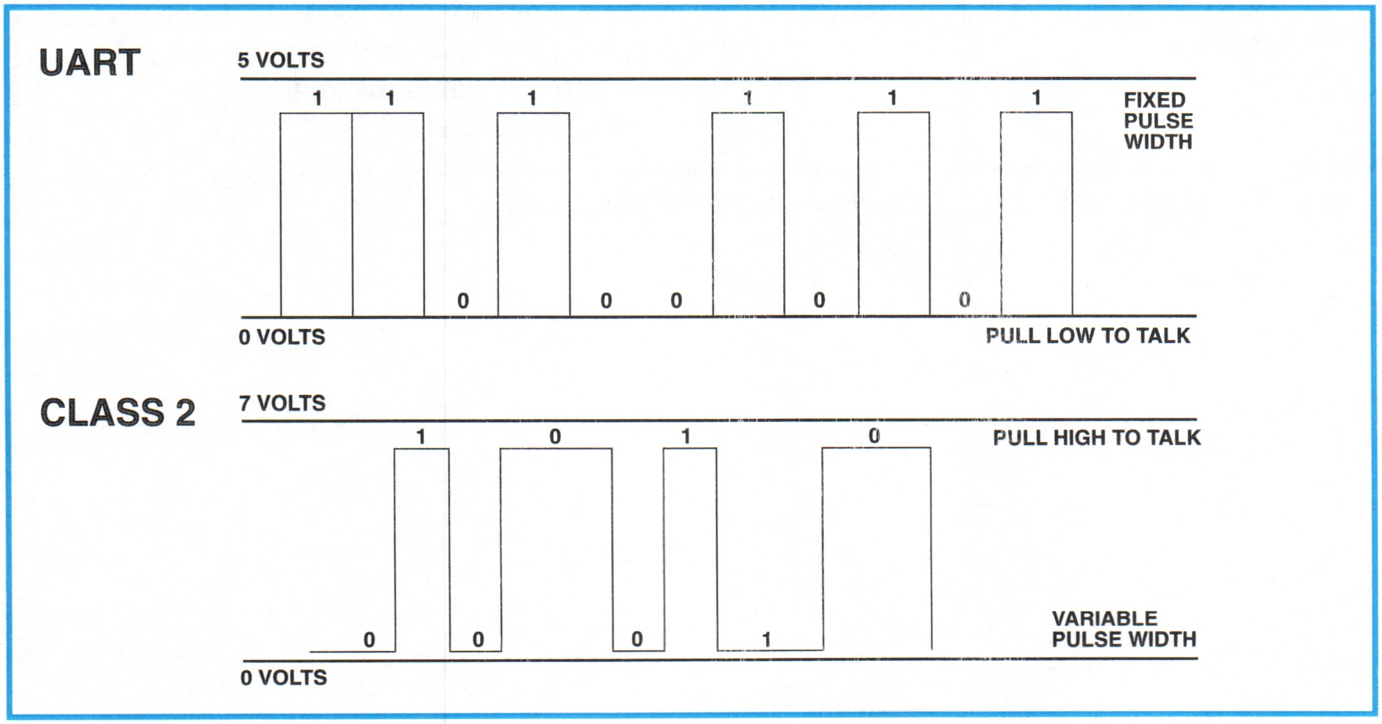


Figure 3-5, UART and Class 2

Serial Communications – Continued

General Motors vehicles typically use either of the two types of serial data:

- Universal Asynchronous Receive and Transmit (UART)
- Class 2

The UART serial data system has been used since the beginning of GM computer control systems. In the UART system, computers communicate on a single wire by pulling the voltage on the data line low when communicating. Therefore, when no communication is occurring on the data line, the system voltage will go to a high level which is usually 5 or 12 volts.

A Class 2 data system allows the data line to go to a voltage near 0 volts when no communication is occurring, and pulls the voltage on the line up to about 7 volts when communicating.

The diagnostic tool needs to be able to communicate using both of these types of serial data to diagnose vehicle systems.

UART/CLASS 2 COMMUNICATION COMPARISON	
UART	**CLASS 2**
• **5 volts**	• **7 volts**
• **Voltage pulled low to talk**	• **Voltage pulled high to talk**
• **All bits equal width**	• **2 bit widths used**
• **Messages sent as a continuous stream**	• **Messages sent in packets. Packets can have priorities so more than one controller can send messages simultaneously**

Figure 3-6, **UART and Class 2 Communication Differences**

Each digital signal is called a “bit” and represents a number. The computer strings together a series of these “bits” to make “words.” Eight “bits” make a “word.” Serial data means that each word is read in order, one at a time, in a series. A typical serial data stream may have 64 words on it.

To help simplify this, think back to the last time you went shopping. In many stores your purchases are rung up automatically by “scanners.” A bar code on the package interrupts a light beam creating a series of digital signals.

These signals are then translated by the microprocessor into a number which represents that product. Your purchase is automatically registered and charged out on the cash register.

The TECH 2 reads serial data in a similar way. By interfacing with Serial Data Lines through the Serial Data Link at the DLC, the TECH 2 can read the serial data that is being sent between the various components of the electronic system being tested.

Baud Rate

A serial data stream contain bits, each bit holding a specific place in the data stream. Bits can represent a message being sent or a separation between messages. These bits are being sent at precise time intervals. The speed at which bits are transmitted is known as “Baud Rate.”

Since the late 1980’s the baud rate of most GM products has been 8192. In other words, there are 8192 bits per second being transmitted on the Serial Data Line. Beginning in 1995, some GM vehicles started using a baud rate of approximately 10400 (10.4K) bits per second. From 1996 on into the future, most GM vehicles will communicate at this faster rate.

The Auto Disconnect receives its keep alive voltage directly from the battery pack. It receives 320 volts from circuits connected to the contactors. The 320 volts is stepped-down to 12 volts inside the Automatic Disconnect.

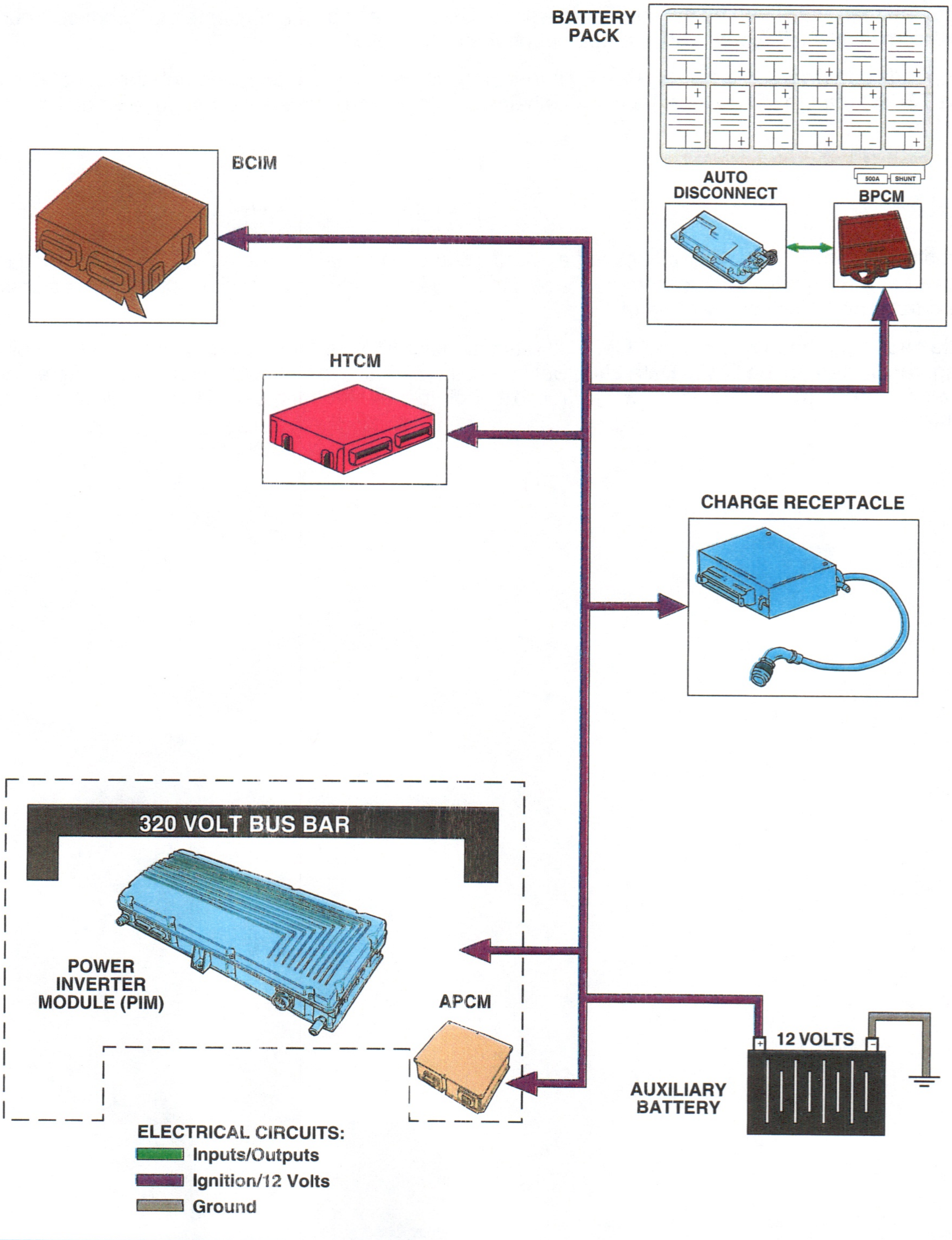

BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
BCIM
HTCM
CHARGE RECEPTACLE
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Inputs/Outputs
Ignition/12 Volts
Ground

Figure 3-7, Keep Alive Voltage Block Diagram

Keep Alive Voltage

Many of the control modules on the S10 electric truck require 12-volt power at all times to retain volatile memory. The BPCM and auto disconnect require 12 volts at all times to remain "awake" to monitor the high voltage system. The charge receptacle must also stay "awake" to receive the charging signal from the charging station and to communicate with the BPCM.

The following control modules receive keep alive voltage (refer to Figure 3-7):

- Heating and Thermal Control Module (HTCM)
- Power Inverter Module (PIM)
- Body Control Interface Module (BCIM)
- Battery Pack Control Module (BPCM)
- Charge Receptacle
- Auto Disconnect
- Accessory Power Control Module (APCM)

In addition to the control modules, there are many components that require 12 volts regardless of the ignition switch position. Refer to the Accessory Power System section for further information on the 12-volt system.

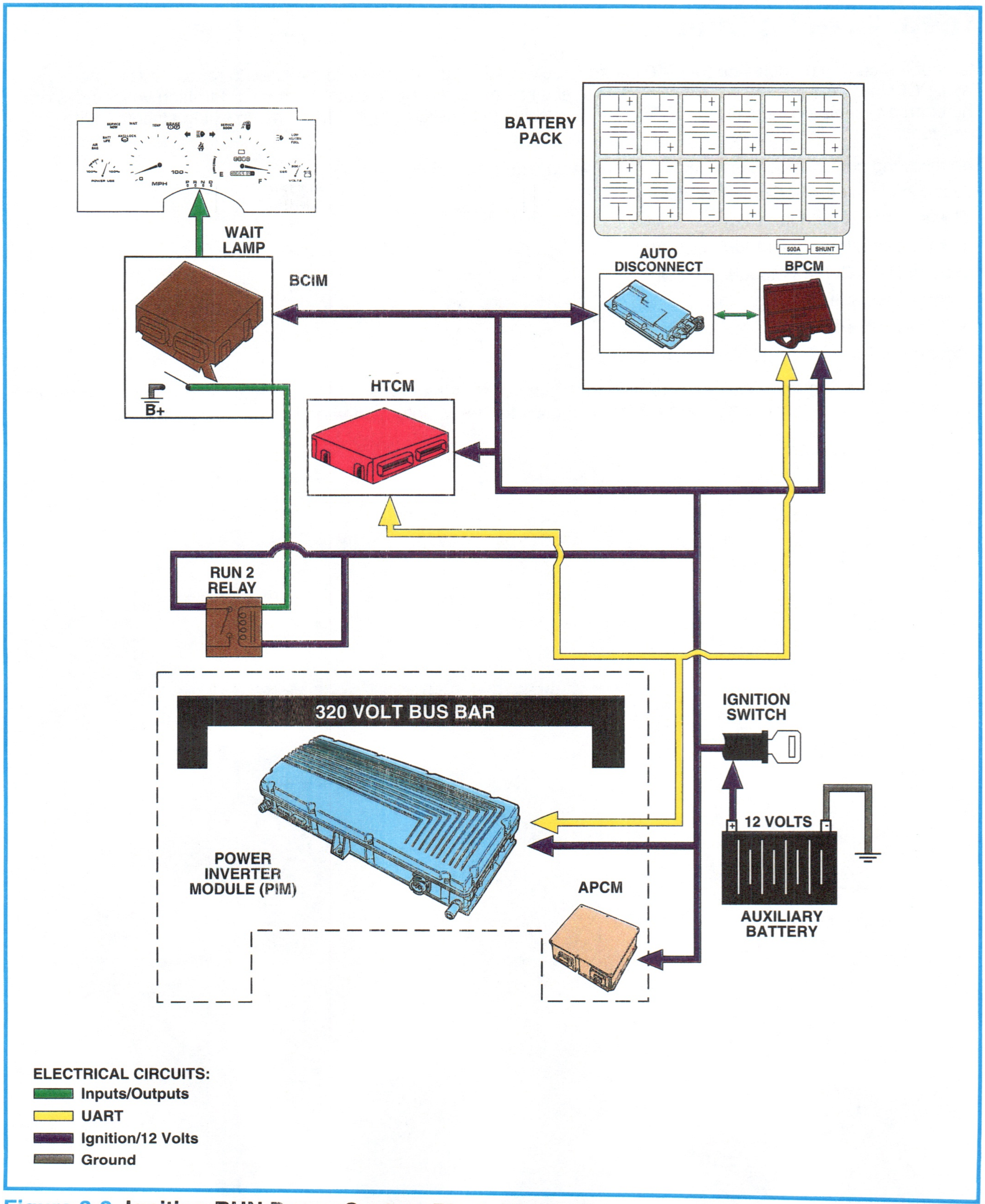

BATTERY PACK
WAIT LAMP
BCIM
AUTO DISCONNECT
500A
SHUNT
BPCM
HTCM
B+
RUN 2 RELAY
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
+
-
POWER INVERTER MODULE (PIM)
APCM
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Inputs/Outputs
UART
Ignition/12 Volts
Ground

Figure 3-8, Ignition RUN Power System Block Diagram

Figure 3-8 on the facing page applies to the 1997 Electric S10.

Notes

In 1998, the switch side of the RUN 2 Relay is Hot At All Times.

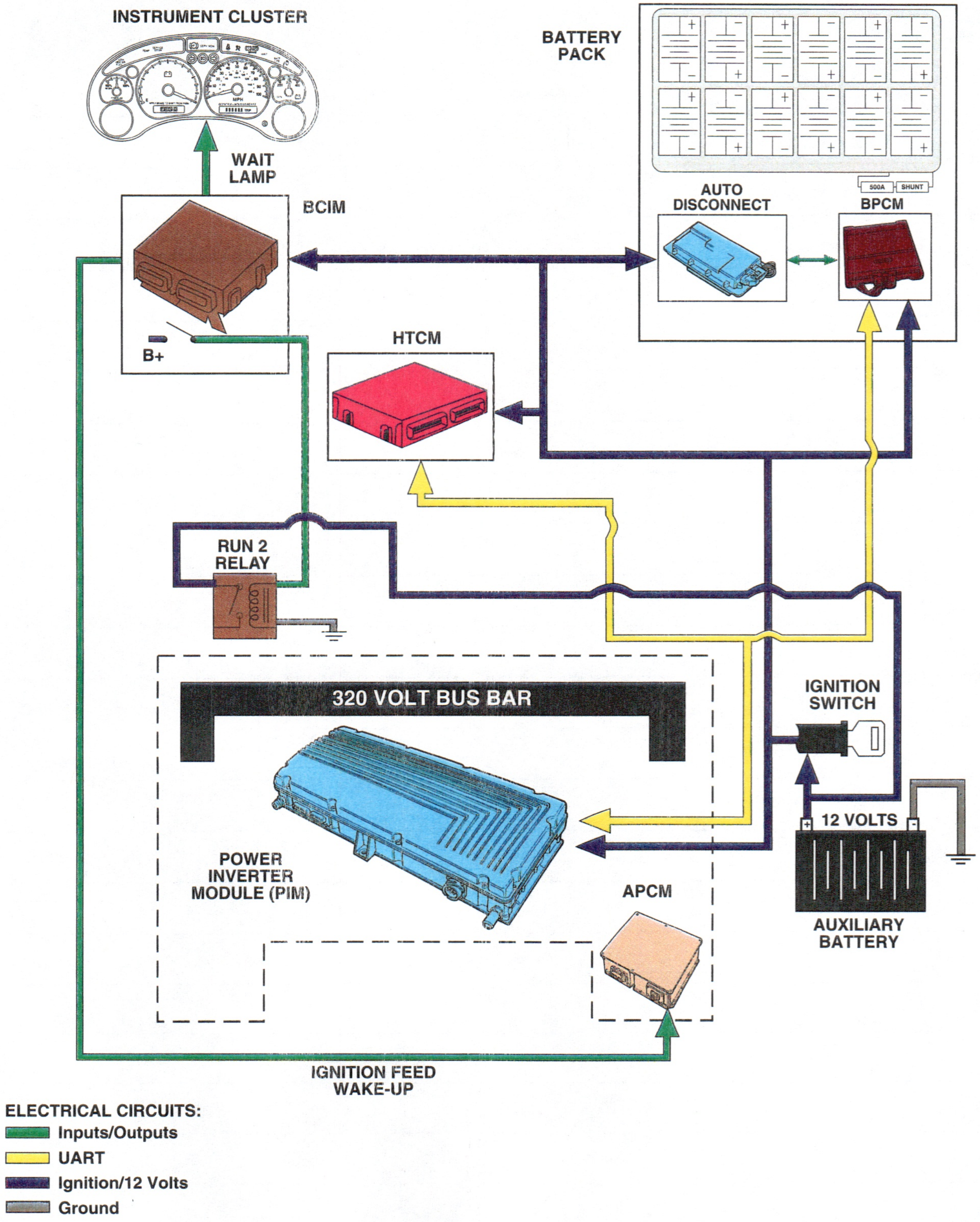

INSTRUMENT CLUSTER
BATTERY PACK
WAIT LAMP
BCIM
500A
SHUNT
AUTO DISCONNECT
BPCM
B+
HTCM
RUN 2 RELAY
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
+
-
POWER INVERTER MODULE (PIM)
APCM
AUXILIARY BATTERY
IGNITION FEED WAKE-UP
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟦 Ignition/12 Volts
⬜ Ground

Figure 3-8a, Ignition RUN Power System Block Diagram

Ignition RUN Power System

When the ignition switch is turned to the run position, a series of events occur that prepare the high voltage system for propulsion:

- Systems are provided ignition voltage wake-up.
- Testing is performed by the Power Inverter Module (PIM), Battery Pack Control Module (BPCM) and the Heating and Thermal Control Module (HTCM).
- The Body Control Interface Module (BCIM) may illuminate the WAIT lamp in the instrument cluster.
- The high voltage system is slowly energized (only if the high voltage circuit is in the discharged state).
- If testing is completed and no DTCs are set that prohibit propulsion, the RUN 2 relay will be energized by the BCIM.
- The RUN 2 relay provides voltage to specific control modules to signal that propulsion is enabled.

The following components (required for propulsion) receive a 12-volt ignition "wake-up" signal when the ignition switch is in the RUN position (refer to Figure 3-8):

- Heating and Thermal Control Module (HTCM)
- Accessory Power Control Module (APCM)
- Power Inverter Module (PIM)
- Body Control Interface Module (BCIM)
- Battery Pack Control Module (BPCM)
- Auto Disconnect
- RUN 2 relay

In addition to the components listed above there are many other components and control modules that receive power through the ignition switch. Refer to the Accessory Power System section.

When the ignition switch is initially turned to the RUN position, most control modules receive an ignition switch "wake-up." When the "wake-up" is received, the BPCM performs testing and monitors the condition of all of the individual battery modules and the temperature of the battery pack. If the BPCM determines that the battery pack status is within acceptable parameters, the BPCM will signal the HTCM on the UART data line that the RUN 2 relay coil can be energized.

Prior to the RUN 2 relay being energized, the PIM also performs testing and will report to the HTCM (using the UART data line) any DTCs that will prevent propulsion. After both the BPCM and PIM provide a RUN 2 request to the HTCM, the HTCM will signal the BCIM to provide a ground to the RUN 2 relay coil.

If the high voltage line is in the discharged state (resulting from the contactors being open), the BPCM and Auto Disconnect will start energizing the high voltage system. The high voltage system is slowly energized by placing a resistance in the high voltage circuit. Once the high voltage system has energized, the resistance is removed. The BPCM will request RUN 2 only after the high voltage system is energized.

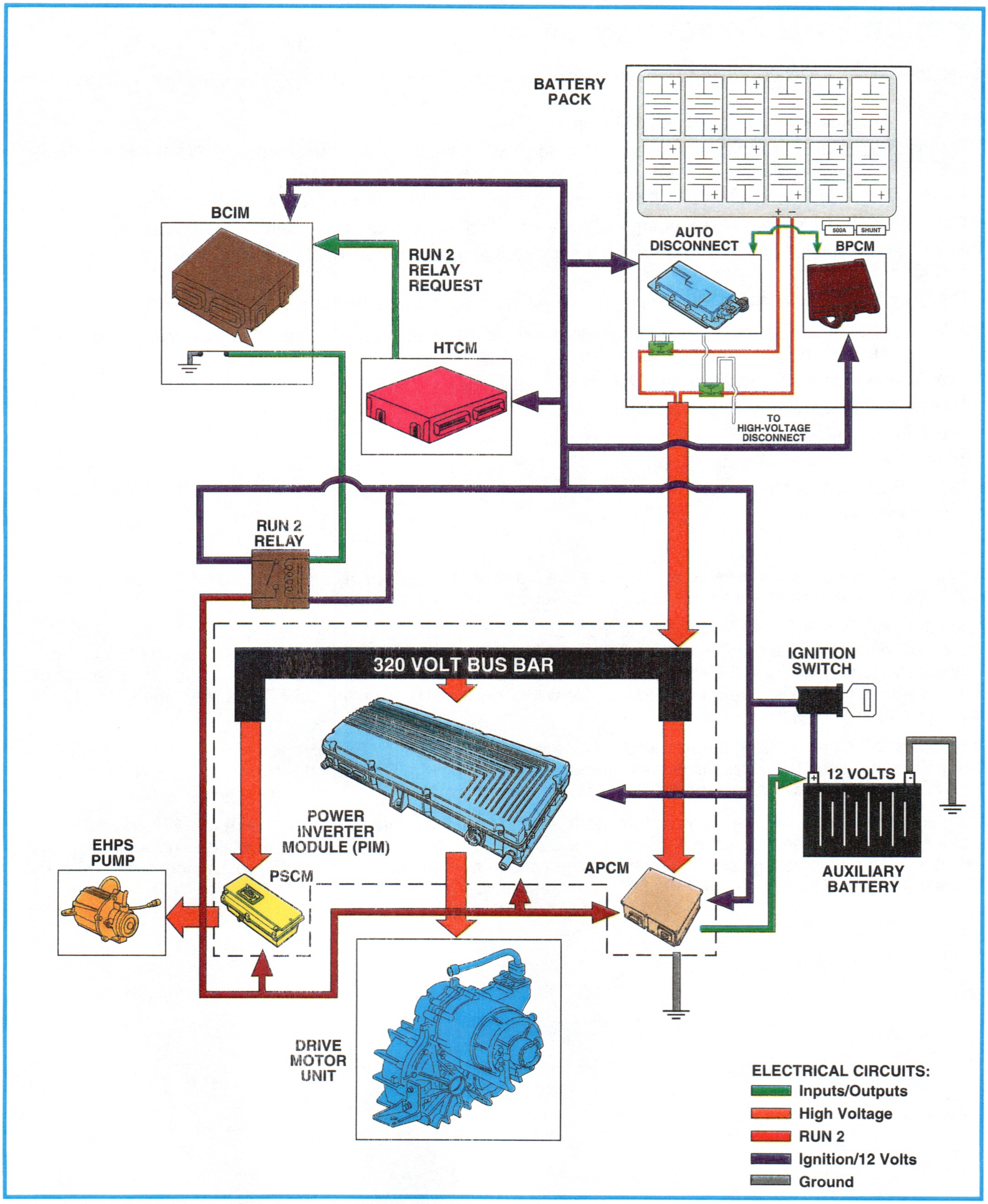

BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
BCIM
RUN 2 RELAY REQUEST
HTCM
TO HIGH-VOLTAGE DISCONNECT
RUN 2 RELAY
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
AUXILIARY BATTERY
POWER INVERTER MODULE (PIM)
PSCM
APCM
EHPS PUMP
DRIVE MOTOR UNIT
ELECTRICAL CIRCUITS:
Inputs/Outputs
High Voltage
RUN 2
Ignition/12 Volts
Ground

Figure 3-9, **RUN 2 Power System Block Diagram**

Figure 3-9 on the facing page applies to the 1997 Electric S10.

Notes

In 1998, the switch side of the RUN 2 Relay is Hot At All Times. The RUN 2 Relay is located in the Underhood Bussed Electrical Center (UBEC).

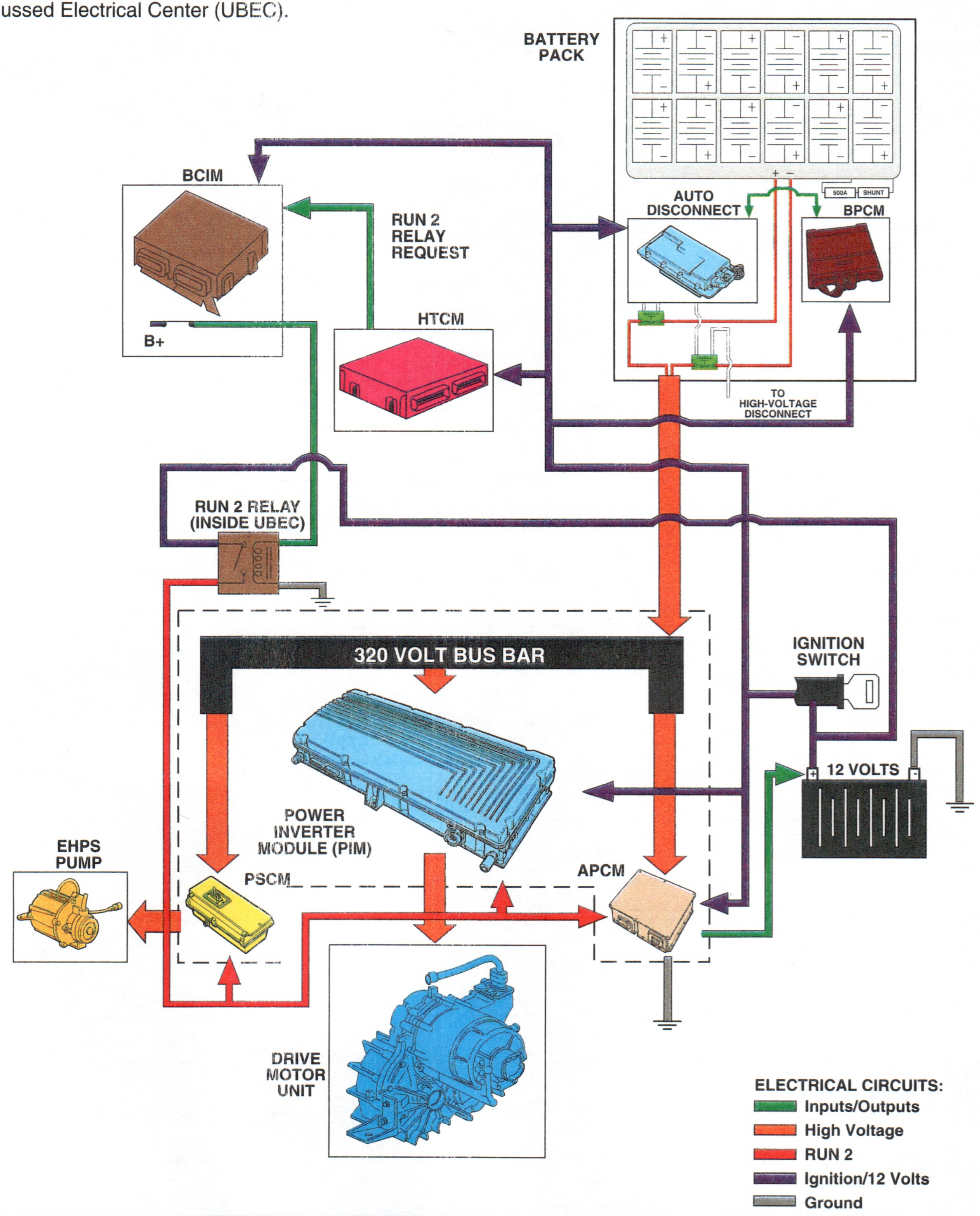

BATTERY PACK
+ −
500A
SHUNT
AUTO DISCONNECT
BPCM
BCIM
B+
RUN 2 RELAY REQUEST
HTCM
TO HIGH-VOLTAGE DISCONNECT
RUN 2 RELAY (INSIDE UBEC)
320 VOLT BUS BAR
IGNITION SWITCH
12 VOLTS
+
-
POWER INVERTER MODULE (PIM)
EHPS PUMP
PSCM
APCM
DRIVE MOTOR UNIT
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟧 High Voltage
🟥 RUN 2
🟪 Ignition/12 Volts
⬜ Ground

Figure 3-9a, RUN 2 Power System Block Diagram

Run 2 Power System

The RUN 2 relay provides the signal that propulsion is enabled. The request to energize the RUN 2 relay is provided by the Battery Pack Control Module (BPCM) and Power Inverter Module (PIM) using the UART data line. These two control modules will provide the request after testing has been successfully completed. When the RUN 2 request is provided to the Heating and Thermal Control Module (HTCM), it provides a RUN 2 request to the BCIM. The BCIM controls the ground side of the RUN 2 relay coil. (Refer to Figure 3-9.)

When the BCIM provides a ground to the RUN 2 relay coil, the RUN 2 relay switch provides 12 volts to the Accessory Power Control Module (APCM), Power Inverter Module (PIM) and the Power Steering Control Module (PSCM). After receiving RUN 2 voltage, the PIM enables propulsion and waits for input from the driver on speed and direction.

When the APCM receives the RUN 2 voltage, it uses the 320-volt battery pack to provide 12 volts to the 12-volt system. The APCM functions like the generator on a gas powered vehicle. Refer to the accessory power system section for more information.

When the PSCM receives RUN 2 voltage, it uses the 320-volt battery pack to energize the Electro-Hydraulic Power Steering (EHPS) pump. Refer to the Power Steering System section for more information.

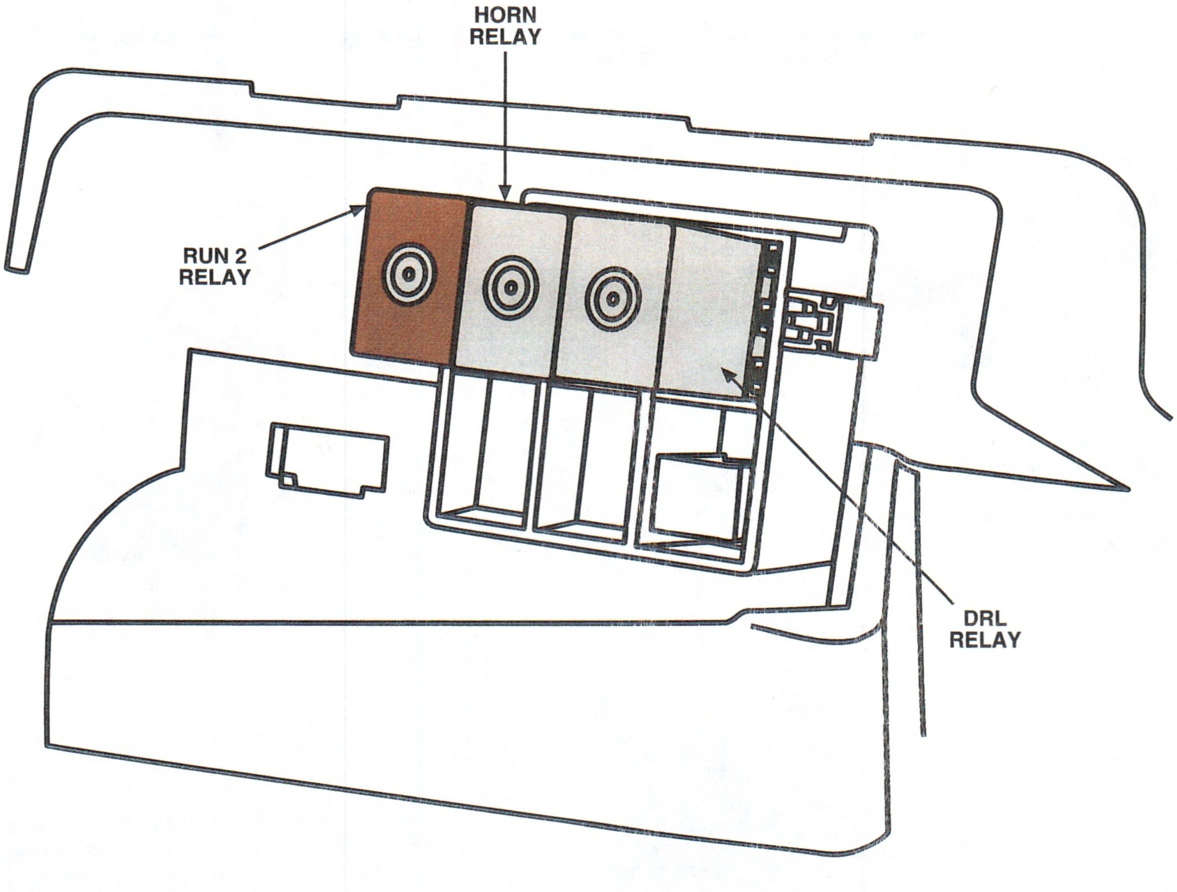


Figure 3-10, **Run 2 Relay Location**

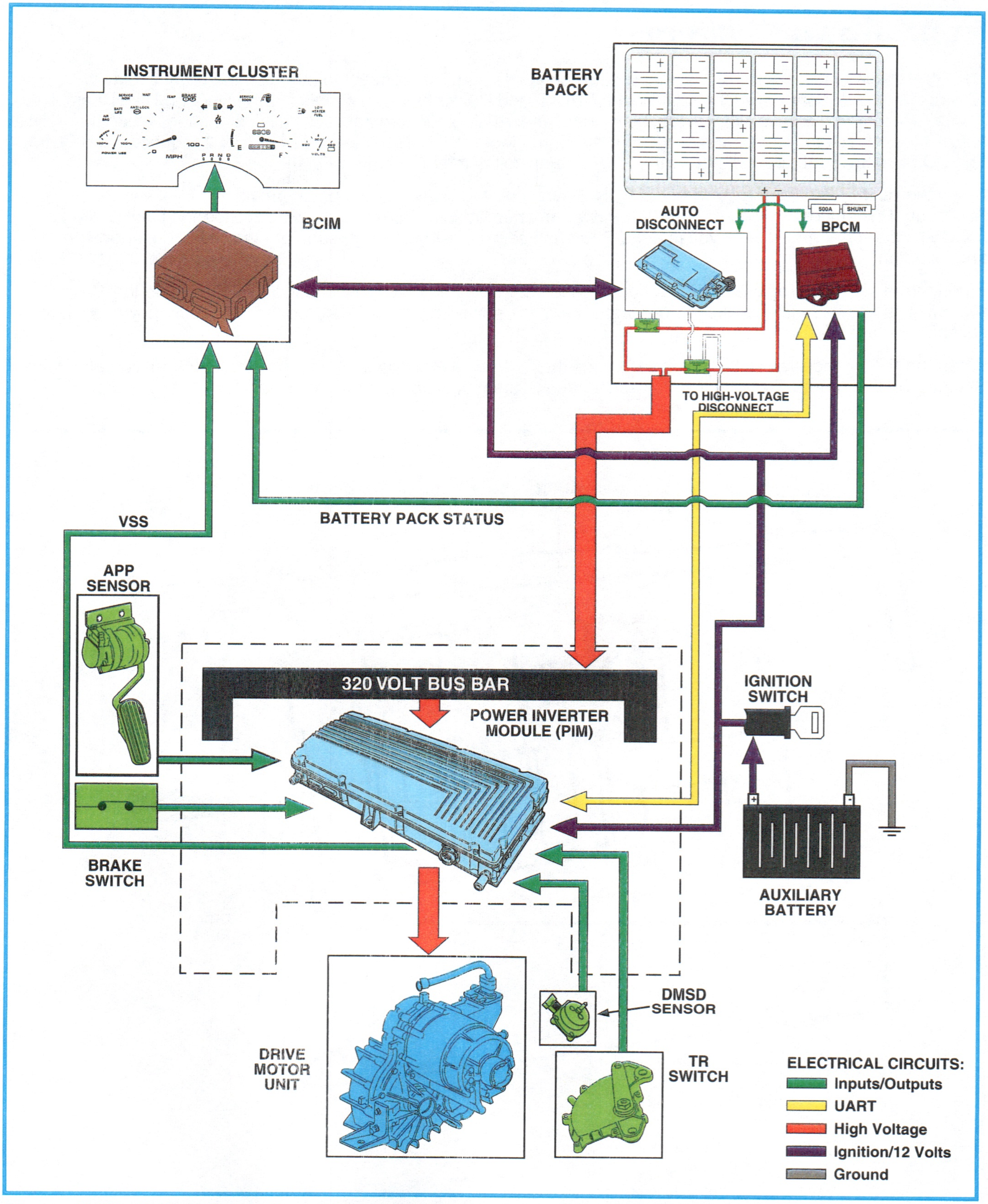

INSTRUMENT CLUSTER
BATTERY PACK
BCIM
AUTO DISCONNECT
500A
SHUNT
BPCM
TO HIGH-VOLTAGE DISCONNECT
VSS
BATTERY PACK STATUS
APP SENSOR
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
IGNITION SWITCH
BRAKE SWITCH
AUXILIARY BATTERY
DMSD SENSOR
DRIVE MOTOR UNIT
TR SWITCH
ELECTRICAL CIRCUITS:
Inputs/Outputs
UART
High Voltage
Ignition/12 Volts
Ground

Figure 3-11, Drive Motor Speed and Direction Block Diagram

Figure 3-11 on the facing page applies to the 1997 Electric S10.

Notes

3. Drive Motor System Operation (1998 Update)

In 1998, the BPCM communicates with the Instrument Cluster on the Class 2 data line. The Instrument Cluster receives the vehicle speed signal from the Truck Body Control (TBC) module. The TBC module receives the vehicle speed signal from the PIM.

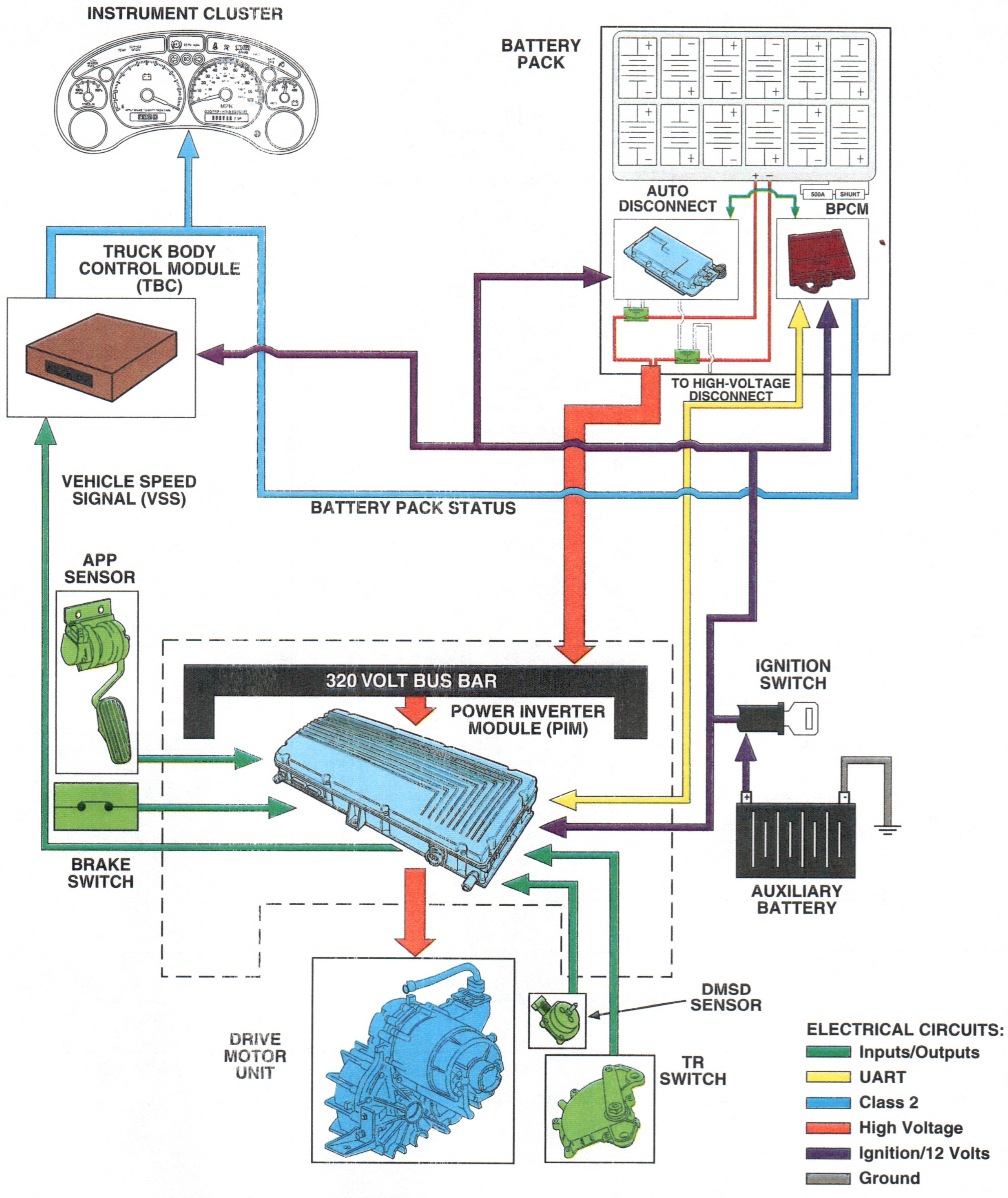

INSTRUMENT CLUSTER
BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
TRUCK BODY CONTROL MODULE (TBC)
TO HIGH-VOLTAGE DISCONNECT
VEHICLE SPEED SIGNAL (VSS)
BATTERY PACK STATUS
APP SENSOR
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
IGNITION SWITCH
BRAKE SWITCH
AUXILIARY BATTERY
DMSD SENSOR
DRIVE MOTOR UNIT
TR SWITCH
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟦 Class 2
🟥 High Voltage
🟪 Ignition/12 Volts
⬜ Ground

Figure 3-11a, Drive Motor Speed and Direction Block Diagram

Propulsion

The drive motor is a three-phase Alternating Current (AC) induction motor. The following are the major components of the drive motor:

- Field Windings
- Rotor
- Drive Motor Speed and Direction (DMSD) Sensor
- Drive Motor Gear Set:
  - Reduction gear set
  - Differential gear set

Drive motor operation is primarily controlled by the Power Inverter Module (PIM). The PIM processes inputs from the vehicle operator and inputs from other systems to determine the control of the drive motor (refer to Figure 3-11).

The PIM converts the 320-volt Direct Current (DC) from the drive motor battery pack into 320-volt Alternating Current (AC). The PIM then controls the three AC phases of the drive motor based on inputs from the vehicle operator (see Figure 3-12). The PIM can control the following operation characteristics of the drive motor:

- Rotor speed
- Rotor direction
- Motor torque

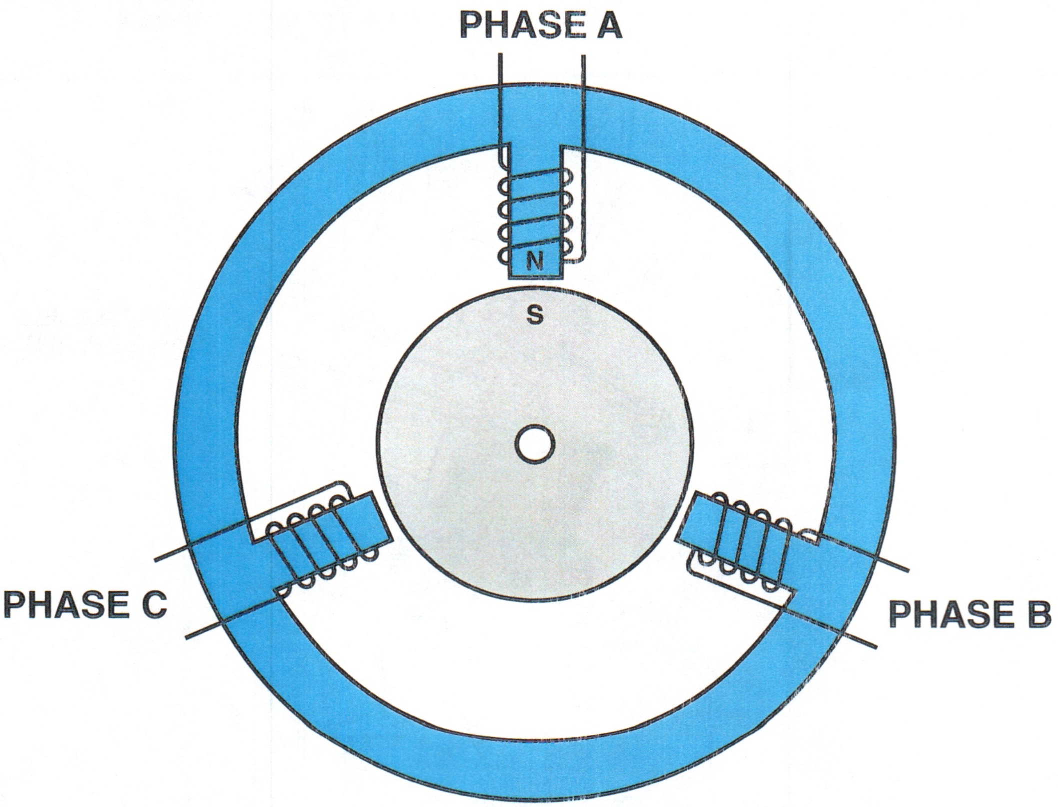


Figure 3-12, **Drive Motor**

TR Range	TR Connector Terminals			
	A	B	C	D
P	Low	High	High	Low
R	Low	Low	High	High
N	High	Low	High	Low
D	High	Low	Low	High

Low = signal on the circuit is provided ground by the TR switch (≈OV)

High = signal on the circuit is NOT provided ground by the TR switch (≈12V)

Figure 3-13, **Transmission Range (TR) Switch Operation**

Propulsion – Continued

During normal operation, the PIM controls the drive motor based on inputs from the vehicle operator. The primary vehicle operator inputs for drive motor operation are:

- Transmission Range (TR) Switch
- Accelerator Pedal Position (APP) Sensor
- Brake Switch

The PIM uses the TR switch for desired direction (reverse or drive). The APP sensor provides input for desired speed and acceleration. The brake switch input signal indicates the need to stop propulsion and, under certain operating conditions, enables the PIM to start regeneration (charging the 320V battery pack by using the vehicle wheels to drive the motor like a generator).

The TR switch is mounted on the drive motor unit (refer to Figure 3-14). The TR switch is connected to the range selector by a cable. Depending on the range selected by the vehicle operator, the switches in the TR switch will provide different signals to the PIM (refer to Figure 3-13). The TR switch also provides input to the BCIM (for operation of the digital range indicator in the instrument panel) and to the BPCM (to prevent charging out of Park range).

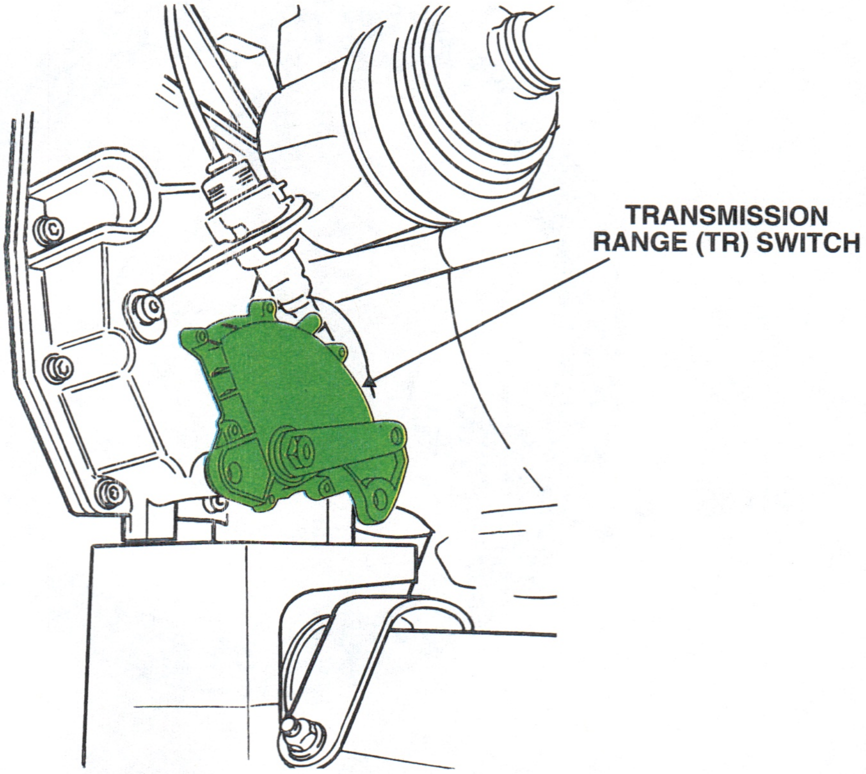


Figure 3-14, **Transmission Range (TR) Switch Location**

Operation of the Accelerator Pedal Position (APP) sensor is similar to that of a Throttle Position (TP) sensor. However, the APP contains three potentiometers. This redundancy allows the PIM to diagnose APP malfunctions and continue operation when one signal is lost. Each potentiometer produces a signal based on the angle of the accelerator pedal. The signal produced by each potentiometer is different from that of the other potentiometers (refer to Figure 3-15).

The APP sensor is located under the driver side instrument panel. The APP sensor is directly connected to the accelerator pedal (see Figure 3-16).

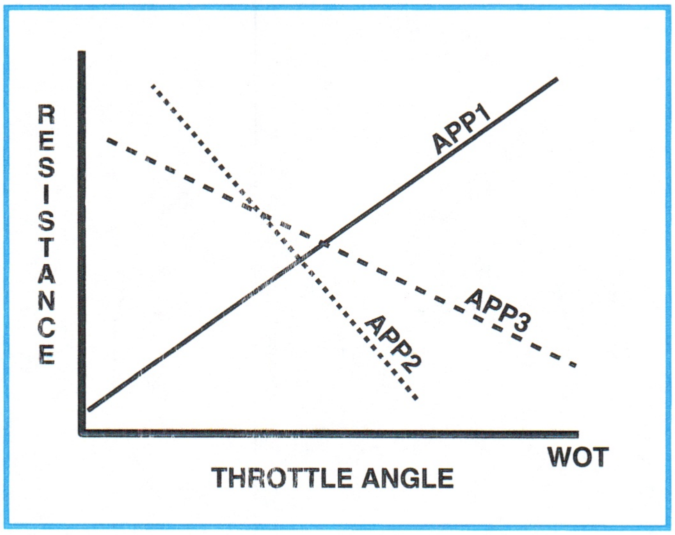


Figure 3-15, APP Sensor Signals

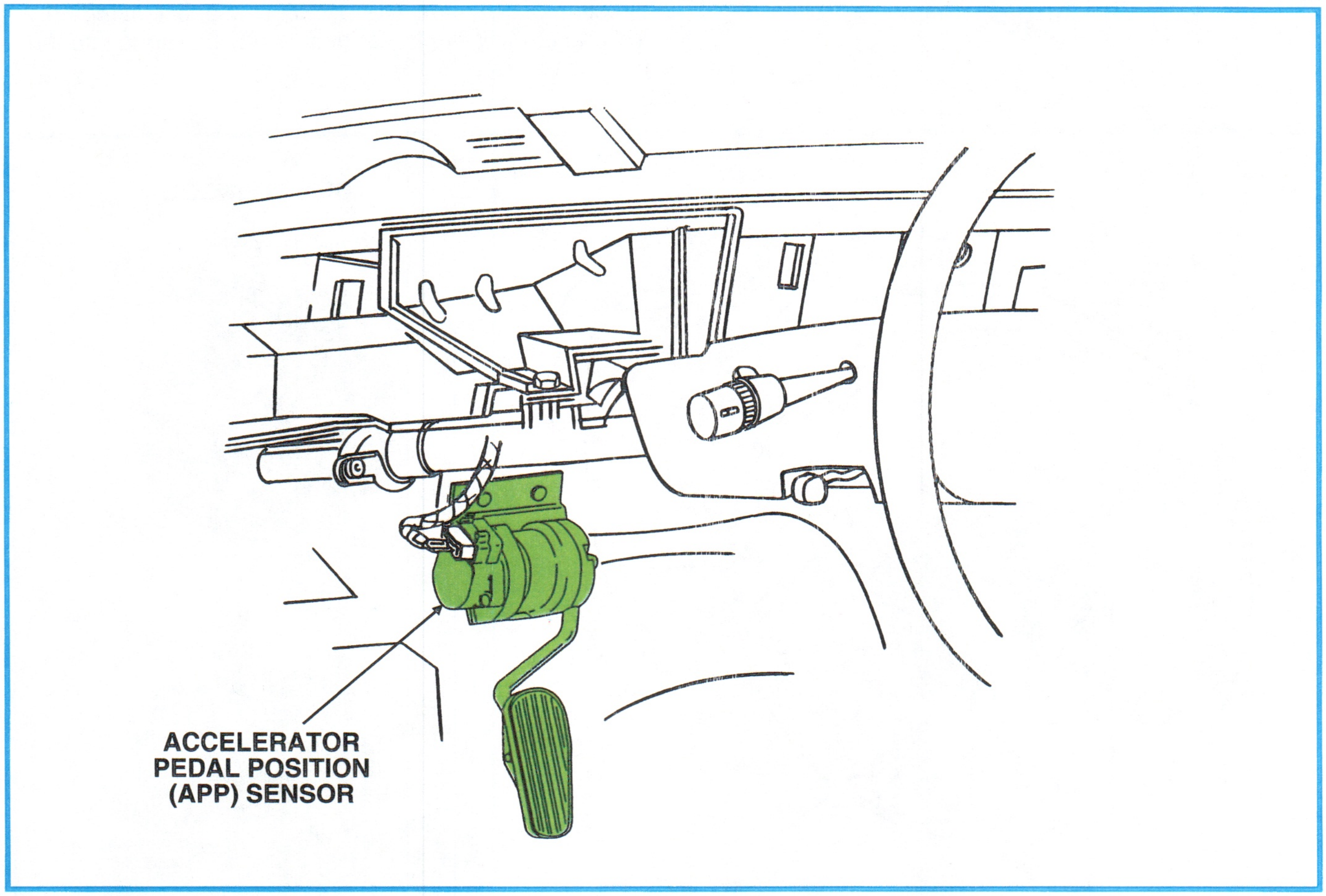


Figure 3-16, APP Sensor Location

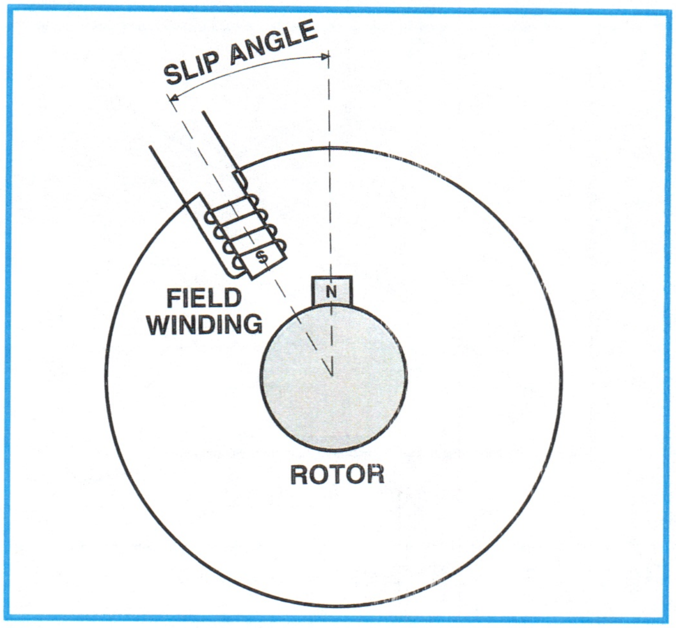


Figure 3-17, Slip Angle

Propulsion – Continued

When the PIM receives input from the TR switch and the APP sensor, it begins propulsion. Based on the APP sensor input, the PIM controls the speed and torque of the drive motor. Motor speed is controlled by how fast the PIM energizes each phase of the field windings (signal frequency). Motor torque is controlled by the amplitude of the high voltage signal generated by the PIM.

A larger amplitude signal will pull the magnetic fields of the rotor harder than a smaller amplitude. By controlling the amplitude, the PIM can control how far the magnetic fields of the rotor lag behind the energizing field windings. The amount of degrees the rotor lags behind the energizing field windings is called the slip angle (see Figure 3-17). A larger commanded slip angle results in less torque produced by the motor.

The PIM uses the Drive Motor Speed and Direction (DMSD) sensor to determine the actual speed and direction of the rotor. The DMSD sensor is located on the end of the drive motor unit, and is threaded into the rotor (see Figure 3-18).

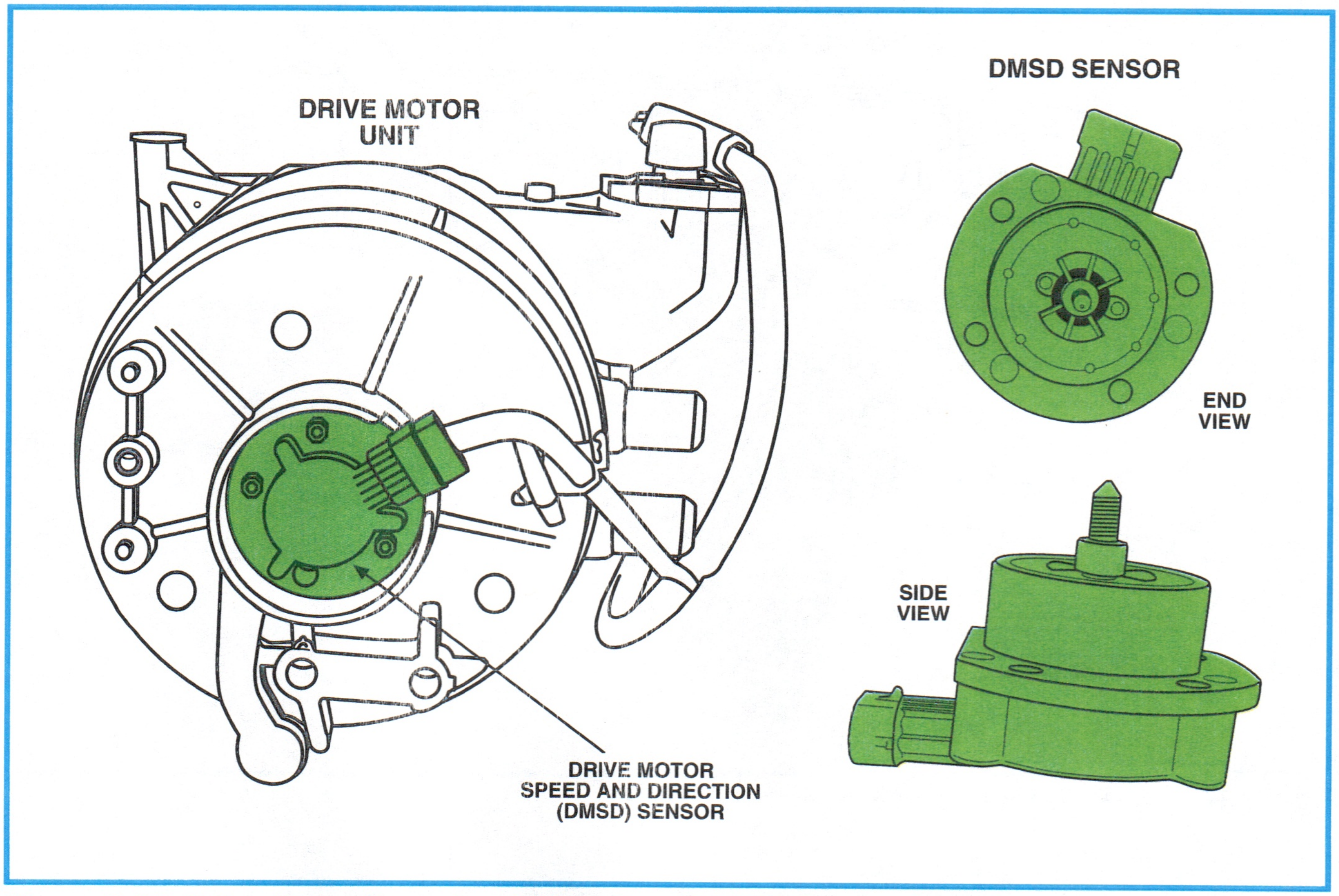


Figure 3-18, Drive Motor Speed and Direction (DMSD) Sensor Location

The PIM also uses the Drive Motor Speed and Direction (DMSD) sensor to determine the actual slip angle. The DMSD sensor operation is similar to the operation of a vehicle speed sensor, except the DMSD sensor produces two alternating signals (refer to Figure 3-19). Depending on which signal leads, the PIM can determine the actual direction of rotor rotation. The frequency of the signals is used to determine the actual rotor speed. This speed signal is also used in the calculation of vehicle speed.

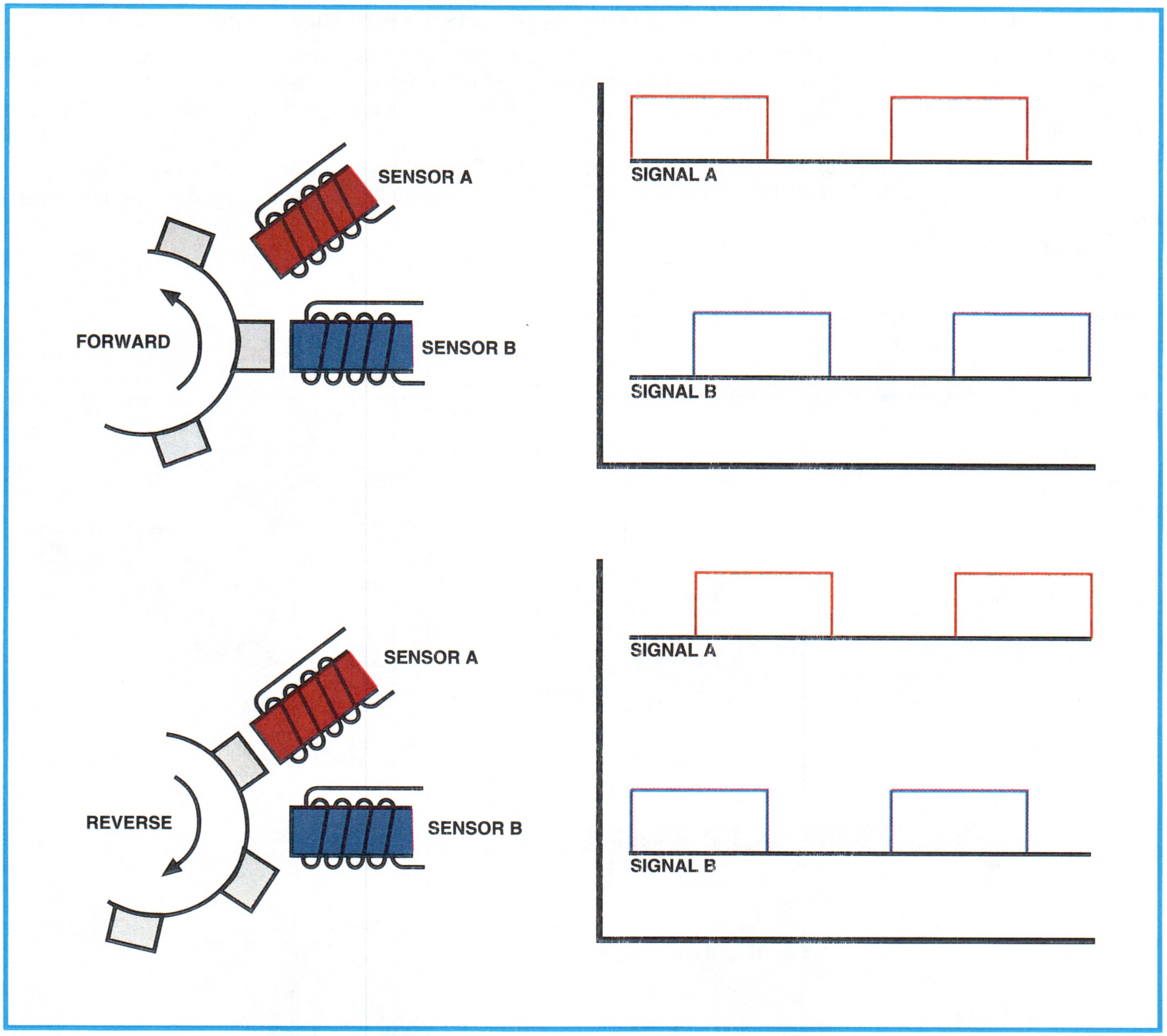

SENSOR A
FORWARD
SENSOR B
SIGNAL A
SIGNAL B
SENSOR A
REVERSE
SENSOR B
SIGNAL A
SIGNAL B

Figure 3-19, Drive Motor Speed and Direction (DMSD) Sensor Operation

Propulsion – Continued

The brake switch is used to signal the PIM to stop propulsion. Propulsion is also stopped when the APP sensor indicates a minimum accelerator pedal angle while the vehicle is moving. After the APP or brake switch signal indicates that propulsion should be stopped, the PIM will either allow the motor to coast or the PIM will begin regeneration (regenerative braking). This is dependent on battery pack state-of-charge, vehicle speed and other operating conditions. During regenerative braking, the drive motor operates like a generator – using the speed of the wheels to drive the rotor and induce a current in the field windings (see Regeneration for more information).

The PIM also uses inputs from other systems and components for drive motor operation (refer to Figure 3-20). The PIM uses the coolant temperature and drive motor winding temperature sensors to determine when PIM and drive motor temperature have exceeded the normal operating range. When the coolant sensor signal indicates 158°F, the PIM will disable propulsion.

The UART serial data line provides the PIM with input from the Heating and Thermal Control Module (HTCM) and the Battery Pack Control Module (BPCM). The HTCM and BPCM can request that propulsion be disabled under the following conditions:

- Battery pack too hot
- Battery pack voltage too low
- Certain battery pack DTCs
- Certain cooling system DTCs

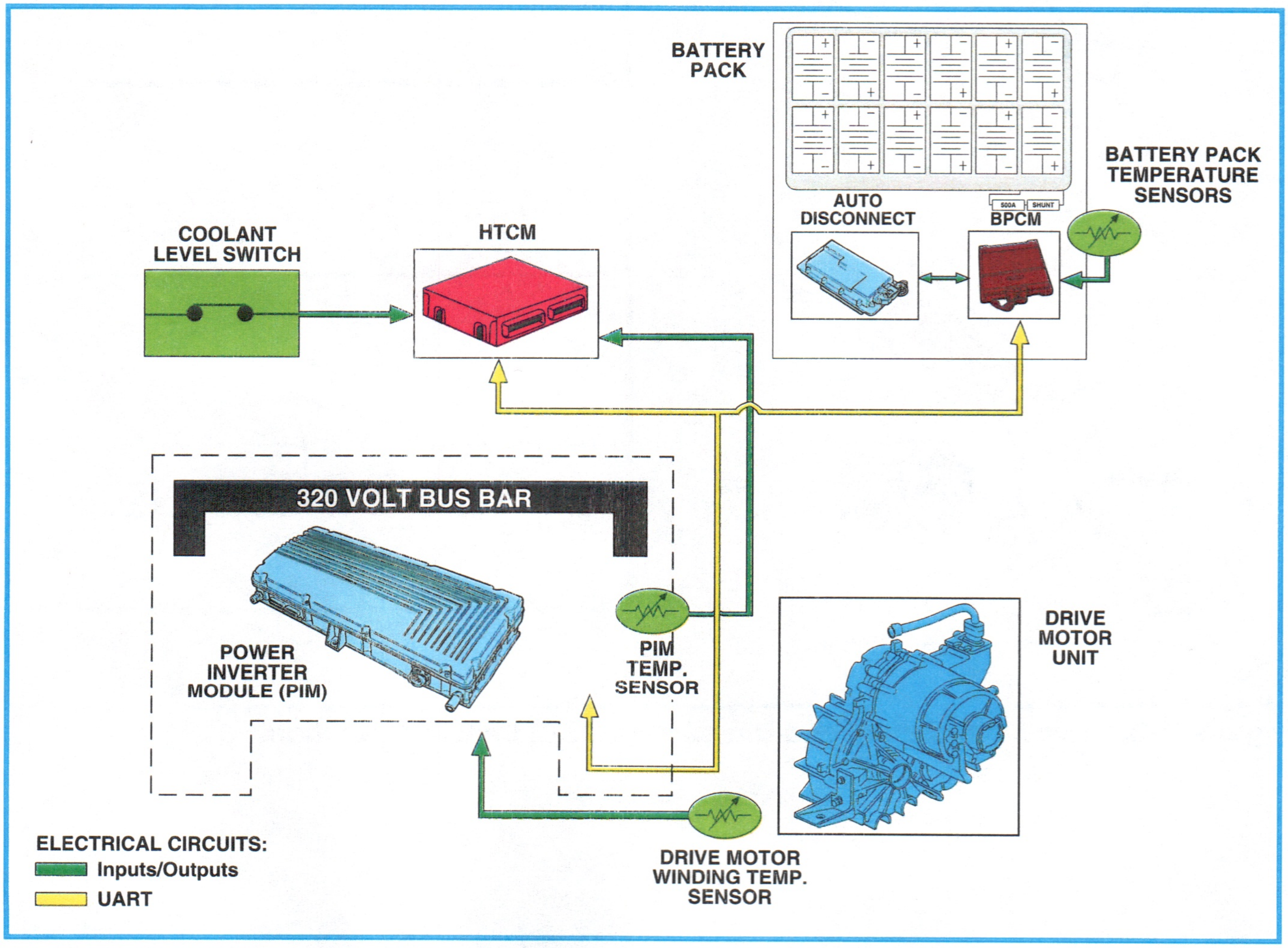

BATTERY PACK
BATTERY PACK TEMPERATURE SENSORS
500A
SHUNT
AUTO DISCONNECT
BPCM
COOLANT LEVEL SWITCH
HTCM
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
PIM TEMP. SENSOR
DRIVE MOTOR UNIT
DRIVE MOTOR WINDING TEMP. SENSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART

Figure 3-20, Drive Motor System Block Diagram

The PIM can communicate with the vehicle operator using the lamps and gauges of the Instrument Cluster. The PIM can either directly control a lamp or it can request (indirect control) the BPCM or Truck Body Control (TBC) module to send a message to the Instument Cluster on the Class 2 data line. The following are the guages and lamps that the PIM has either direct or indirect control over:

- Service Soon lamp (direct control)
- Temp lamp (indirect control, through BPCM)
- Vehicle Speed gauge (indirect control, through TBC)

On the 1997 electric trucks, the PIM was used to provide outputs to the BCIM for Pack Volts and State-of-Charge. The PIM received this information from the BPCM on the UART data line. On the 1998 electric trucks, this information is provided directly to the Instrument Cluster from the BPCM on the Class 2 data line.

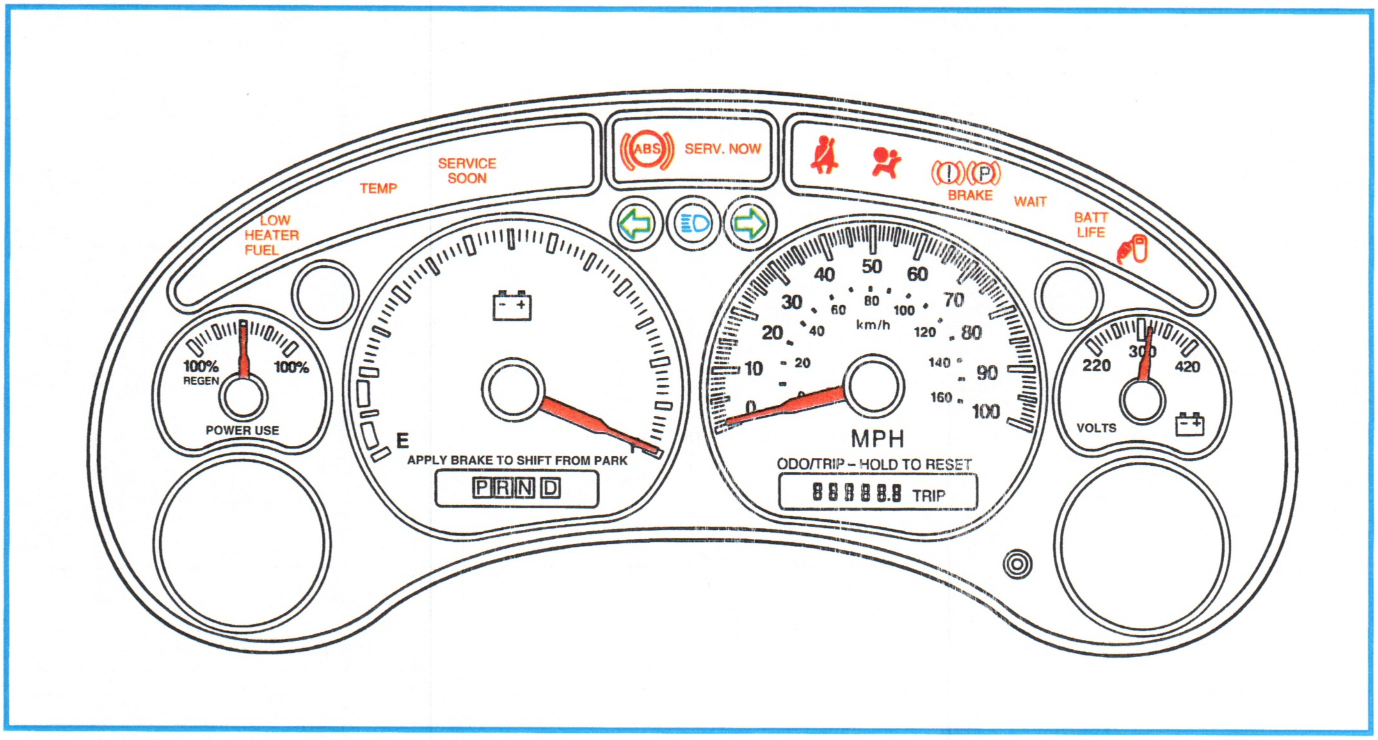

SERVICE SOON
TEMP
LOW HEATER FUEL
ABS
SERV. NOW
BRAKE
WAIT
BATT LIFE
100%
REGEN
100%
POWER USE
E
APPLY BRAKE TO SHIFT FROM PARK
P R N D
40
50
60
30
70
20
80
10
90
0
100
60
80
100
40
120
20
140
160
km/h
MPH
ODO/TRIP – HOLD TO RESET
888888.8 TRIP
220
300
420
VOLTS

Figure 3-21, **Instrument Panel Lamps**

Notes

4. Battery Pack System Operation

Overview

The battery pack system for the electric truck provides high voltage for the drive motor, refrigeration/heat pump system compressor and the power steering pump. The source of the high voltage is contained within the battery pack. Inside the battery pack are 26 battery modules. These battery modules are connected in series and provide 320-volt Direct Current (DC). The battery pack voltage is provided to the high voltage bus inside the PIM though the high voltage circuit. All high voltage circuits are covered with orange conduit.

The PIM converts the DC on the high voltage bus into Alternating Current (AC) and provides AC voltage to the drive motor during propulsion. The high voltage bus inside the PIM also provides voltage to both the Accessory Power Control Module (APCM) and Power Steering Control Module (PSCM). The APCM steps-down the 320-volts DC from the battery pack into 180-volts AC for the Refrigeration/Heat Pump (R/HP) system compressor. The PSCM steps-down the 320-volts DC from the battery pack into 180-volts AC for the Electro-Hydraulic Power Steering (EHPS) pump.

Also inside the battery pack are the Battery Pack Control Module (BPCM), Automatic (Auto) Disconnect and contactors. The BPCM is the main controller for the battery pack system. The BPCM has the ability to monitor individual battery modules for state-of-charge and to command thermal management of the battery pack.

The Auto Disconnect monitors the high voltage circuit. The Auto Disconnect can also disconnect the high voltage source from the high voltage system by opening the two contactors. The contactors are high voltage relays. The Auto Disconnect will open the contactors when either it or BPCM detects a fault. Removing the high-voltage disconnect can also open the contactors.

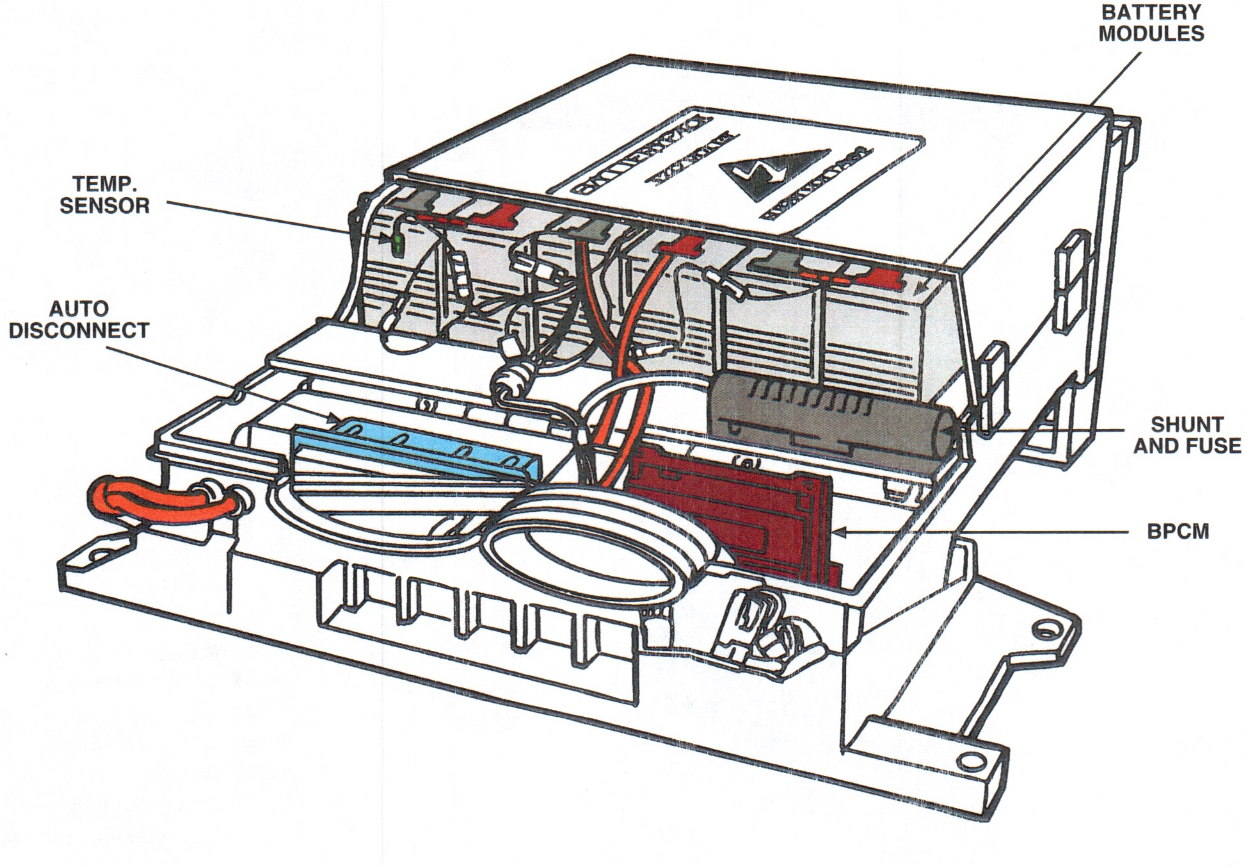


Figure 4-1, Cutaway View of the Battery Pack

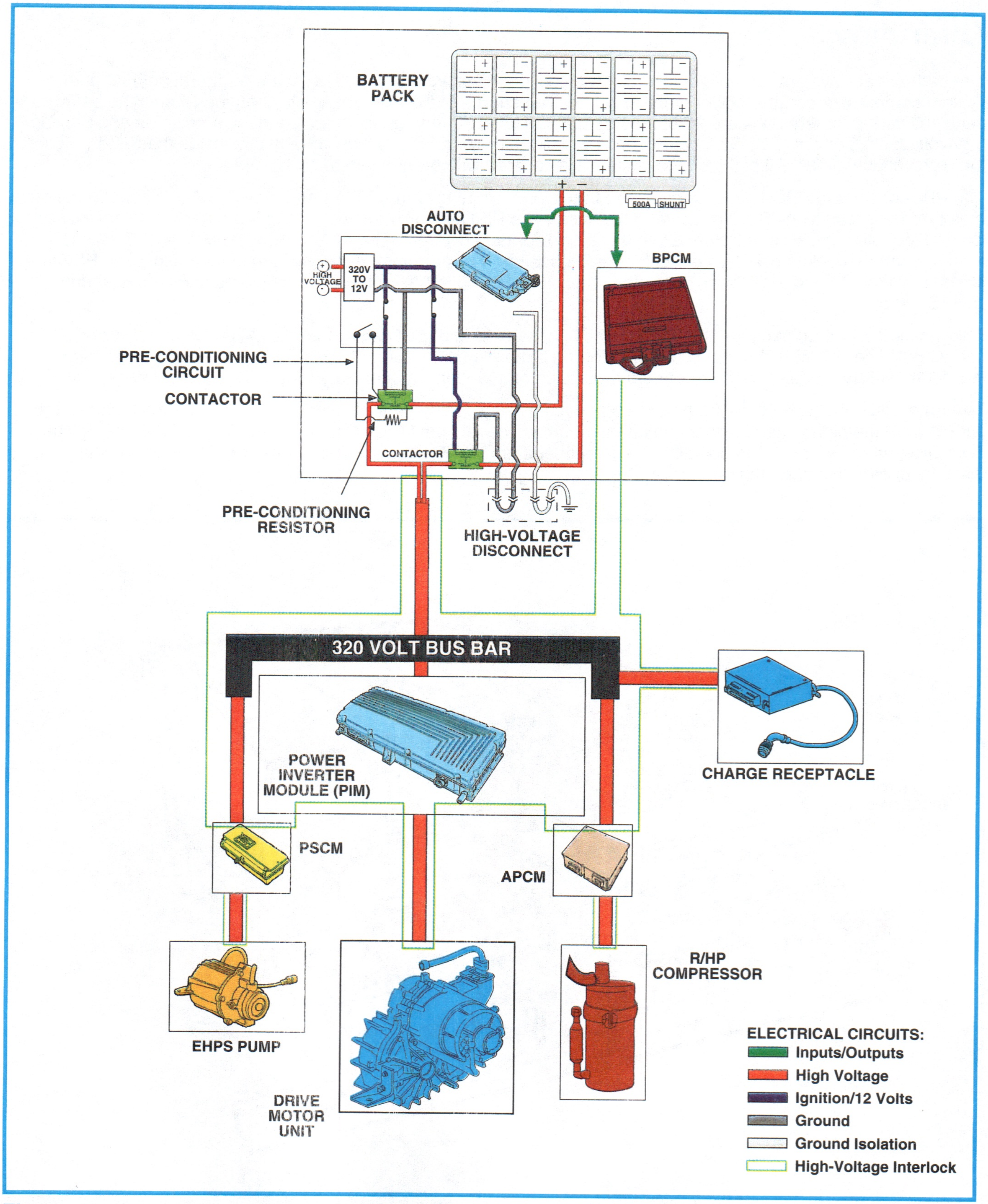

BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
HIGH VOLTAGE
320V TO 12V
PRE-CONDITIONING CIRCUIT
CONTACTOR
CONTACTOR
PRE-CONDITIONING RESISTOR
HIGH-VOLTAGE DISCONNECT
320 VOLT BUS BAR
CHARGE RECEPTACLE
POWER INVERTER MODULE (PIM)
PSCM
APCM
R/HP COMPRESSOR
EHPS PUMP
DRIVE MOTOR UNIT
ELECTRICAL CIRCUITS:
Inputs/Outputs
High Voltage
Ignition/12 Volts
Ground
Ground Isolation
High-Voltage Interlock

Figure 4-2, The Automatic Disconnect and Related Circuits

Automatic Disconnect

The Automatic (Auto) Disconnect provides the ability to disconnect the high voltage source from the high voltage system outside of the battery pack. The Auto Disconnect also monitors the high voltage circuits for opens and shorts to the chassis.

The Auto Disconnect uses two contactors to disconnect the high voltage source from the high voltage system. The contactors are relays with contacts capable of handling high voltage. The coil side of the contactors is controlled by a 12-volt circuit from the Auto Disconnect. The contactors will only be opened if the high-voltage disconnect is removed or a malfunction is detected in the high voltage circuit or source. **Turning the ignition to the OFF position will not cause the high voltage circuits to be discharged.**

To monitor the high voltage system, the Auto Disconnect uses the High Voltage Interlock Loop (HVIL). The high voltage interlock loop is a 12-volt circuit that follows all high voltage circuits:

- Between the battery pack and the PIM
- Between the drive motor and the PIM
- Between the charge receptacle and the PIM
- Between the APCM and the refrigeration system compressor
- Between the PSCM and the power steering pump

If the continuity of the interlock circuit is broken, the Auto Disconnect will open the contactors. When the contactors are opened, the PIM uses internal circuitry to discharge the high voltage bus located within the PIM.

If the contactors have been opened, the BPCM must slowly energize the high voltage bus before charging or propulsion can occur. The BPCM slowly energizes the high voltage system by closing one contactor and placing a resistance circuit in one side of the high voltage circuit. The resistance circuit bypasses the second opened contactor. This allows the PIM to prepare the high voltage system for the high current available from the battery pack. Once the system is charged, the second contactor is closed and the resistance is removed. This process is called pre-conditioning.

The High-Voltage Disconnect is not part of the HVIL circuit. It is a separate circuit that is used to control the operation of the contactors. When the High-Voltage Disconnect connector is removed, it creates an open in the coil circuit of the negative contactor (in 1997, it created an open in both contactor coil circuits) and also creates a chassis ground isolation loss fault. This fault will cause the Automatic Disconnect to open the power feed circuits for both contactor coils.

– CAUTION –

NEVER DISCONNECT ANY HIGH VOLTAGE CONNECTORS WITHOUT FIRST REMOVING THE HIGH-VOLTAGE DISCONNECT CONNECTOR. NOT ONLY COULD YOU BE FATALLY INJURED , BUT THE SURGE OF HIGH VOLTAGE COULD DESTROY VEHICLE COMPONENTS.

Battery Module Voltage Monitoring

The Battery Pack Control Module (BPCM) monitors the state-of-charge of each battery module. The BPCM performs this monitoring to determine:

- If any modules are malfunctioning
- The overall state-of-charge of the battery pack
- The rate of charging

The BPCM has a sensing circuit connected to the positive terminal of each battery module (refer to Figure 4-3). To determine the state of a specific battery module, the BPCM uses the sensing circuit connected to the positive terminal of that battery module and the sensing circuit connected to the next battery module in the series circuit. Since the battery modules are in series, the sensing circuit on the positive terminal can be used by the BPCM to monitor the positive terminal of a specific battery module and also monitor the negative terminal of the next battery module in the series. The BPCM monitors each battery module and compares the result of the measurement to a parameter to determine the status of the battery module.

The BPCM also uses a shunt to monitor battery pack status. This shunt is a precision resistor with very little resistance. The BPCM uses the shunt to electronically split the battery pack for certain tests. The shunt is in series with a fuse. The fuse will split the battery pack voltage in half if there is excessive current flow. The fuse is primarily designed for high voltage component protection. The fuse will most likely provide very little protection from electrocution.

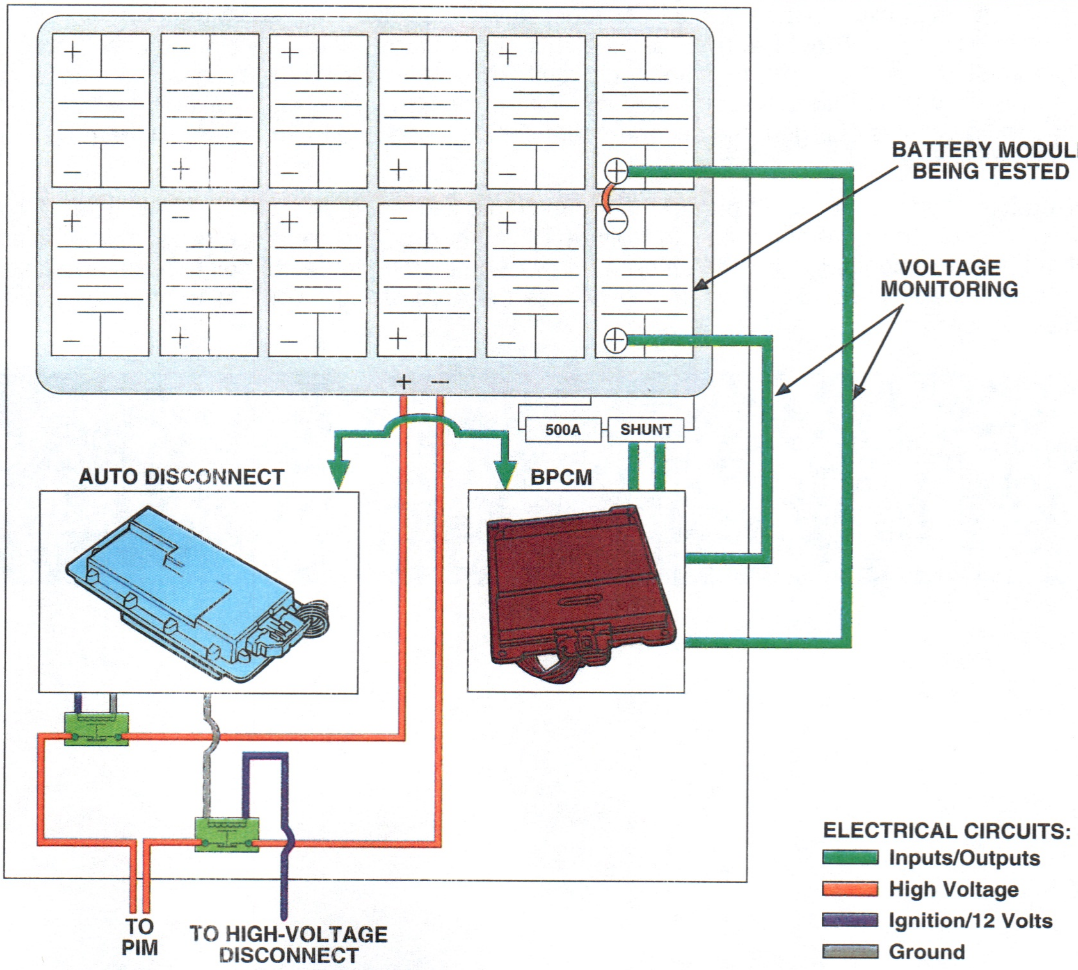

BATTERY MODULE BEING TESTED
VOLTAGE MONITORING
+ −
500A
SHUNT
AUTO DISCONNECT
BPCM
TO PIM
TO HIGH-VOLTAGE DISCONNECT
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage
🟪 Ignition/12 Volts
▨ Ground

Figure 4-3, **Battery Module Voltage Monitoring**

5. Charging System Operation

Overview

The charging system is responsible for charging the 320-volt drive motor battery pack by using the charging station or regeneration. The charging system also charges the 12-volt auxiliary battery (refer to the Accessory Power System section for more information). The charging system has the following components (refer to Figure 5-1):

- Charging Station
- Charge Paddle
- Charge Receptacle
- Power Inverter Module (PIM)
- Battery Pack Control Module (BPCM)
- Heating and Thermal Control Module (HTCM)
- Accessory Power Control Module (APCM)
- 12-Volt Auxiliary Battery
- 320-Volt Drive Motor Battery Pack

The BPCM is the main controller of the charging system. The BPCM regulates the charging rate during normal charging (using the charge station) and regeneration. When the charge paddle is plugged into the charge receptacle, the BPCM provides a "wake-up" voltage to the various systems required for charging.

The APCM controls the charging rate of the 12-volt auxiliary (accessory) battery during both normal battery pack charging and during vehicle propulsion.

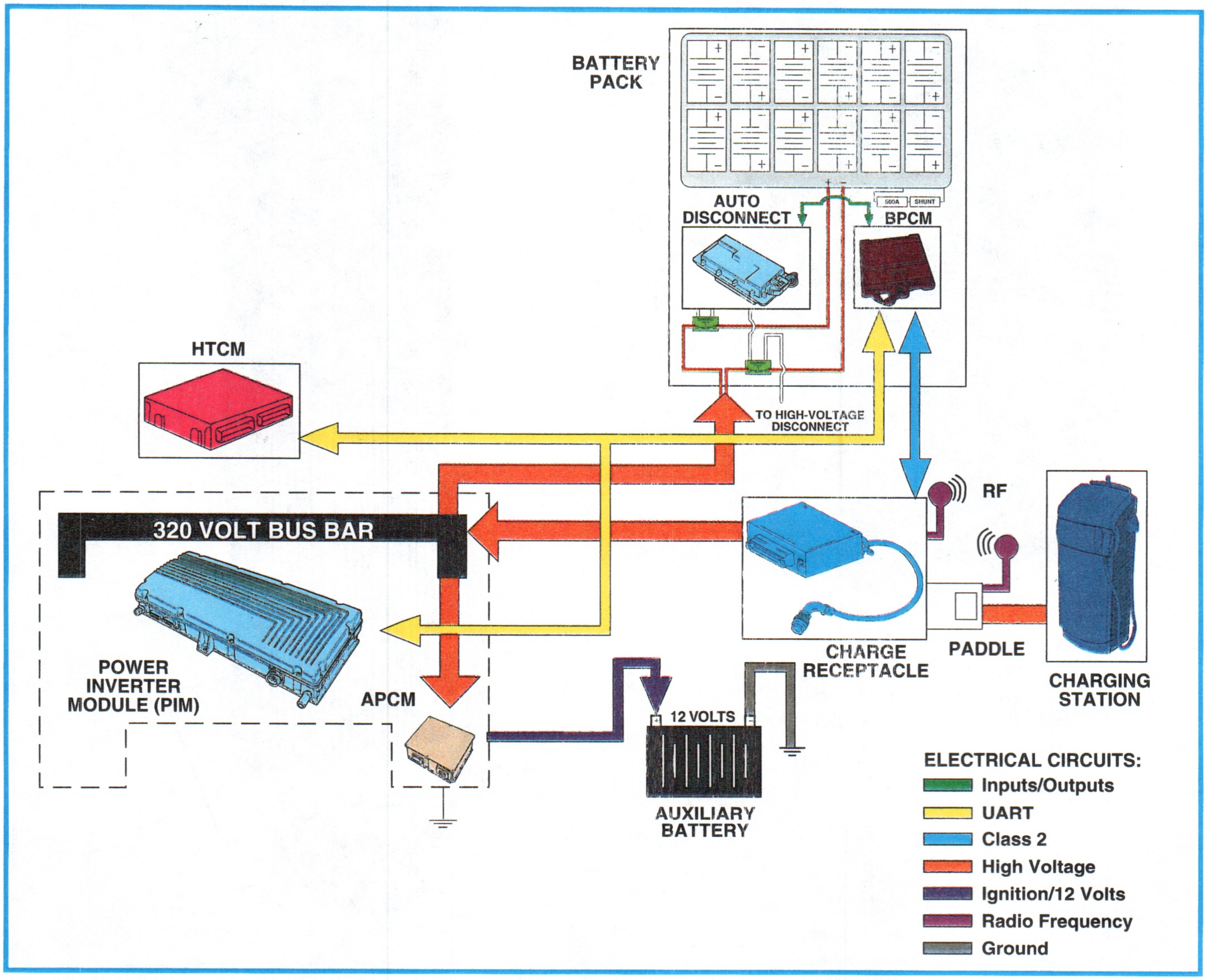

BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
HTCM
TO HIGH-VOLTAGE DISCONNECT
RF
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
12 VOLTS
AUXILIARY BATTERY
CHARGE RECEPTACLE
PADDLE
CHARGING STATION
ELECTRICAL CIRCUITS:
Inputs/Outputs
UART
Class 2
High Voltage
Ignition/12 Volts
Radio Frequency
Ground

Figure 5-1, Charging System

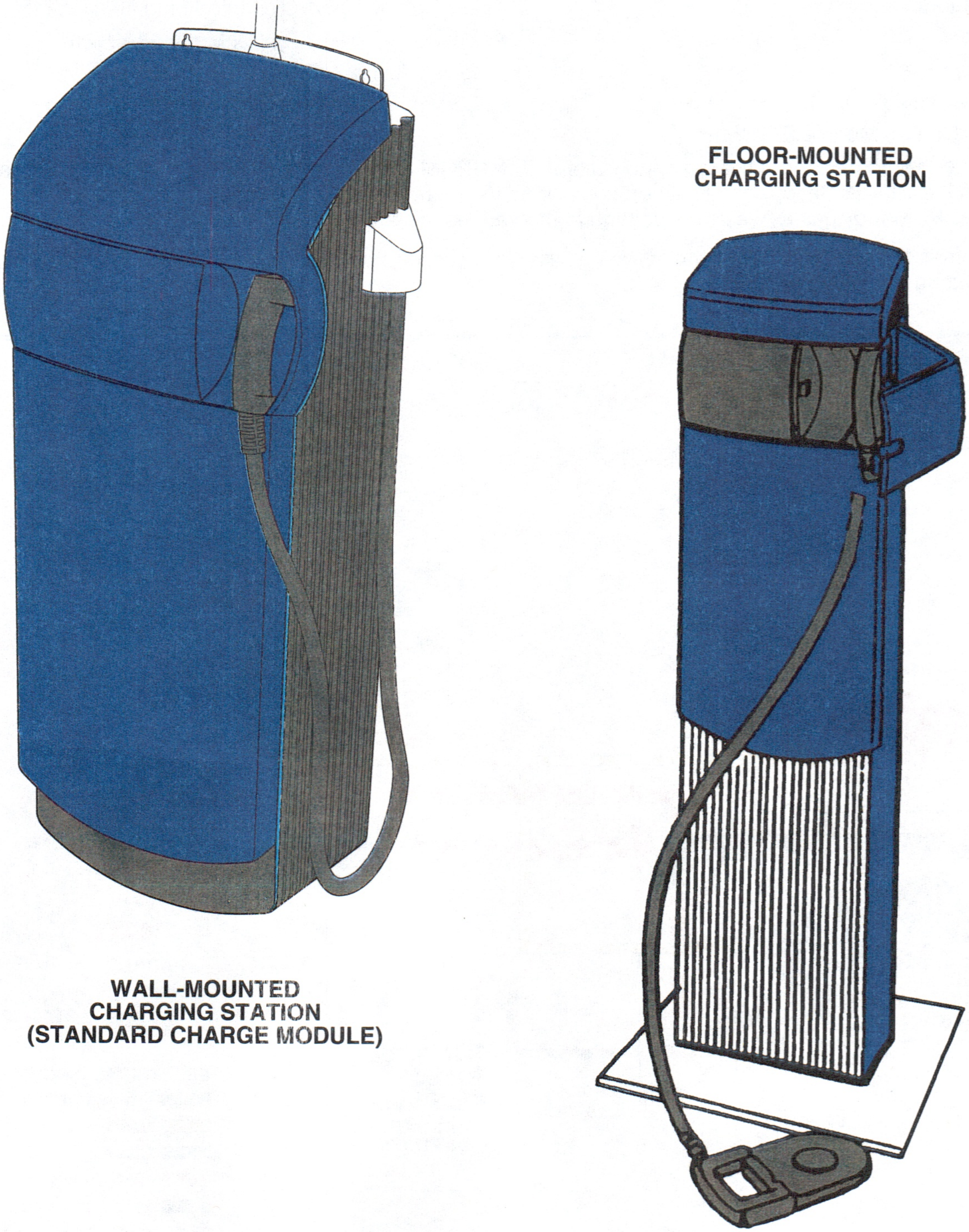

FLOOR-MOUNTED
CHARGING STATION
WALL-MOUNTED
CHARGING STATION
(STANDARD CHARGE MODULE)

Figure 5-2, **Wall-Mounted and Floor-Mounted Charging Stations**

Charging Stations

There are three types of charging stations. Each charging station provides inductive charging through a charge paddle. The charge stations communicate with the BPCM during battery pack charging by using radio frequency signals and the Class 2 data line. The three types of charging stations are as follows (see Figures 5-2 and 5-3):

- Standard Charge Module (SCM)
    - Two models: wall-mounted and floor-mounted.
    - Requires a 30-amp, 240-volt AC feed; its output is 6.6 kW, charging time 2 to 4 hours
- Opportunity Charge Module (OCM)
    - Requires a 3-phase, 32-amps-per-phase, 440-volt AC feed; its output is 25 kW, charging time 15 to 20 minutes
    - Currently not available

Service for charging stations is performed by GM Hughes technicians.

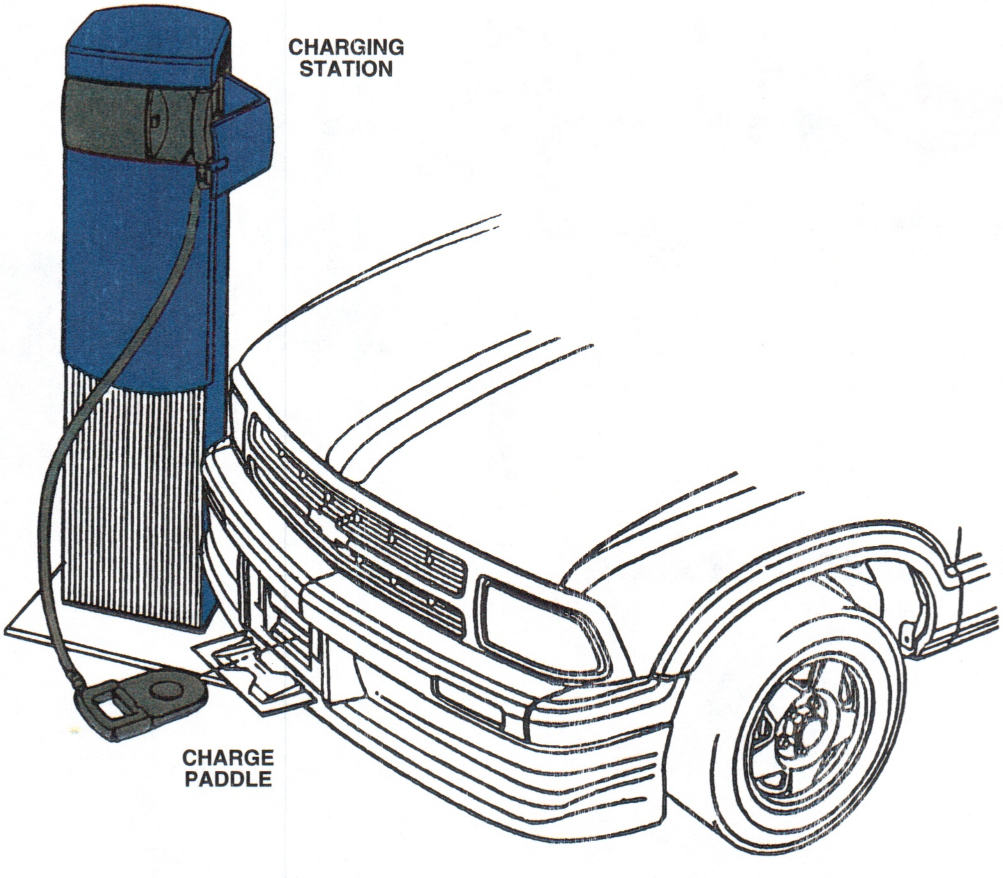


Figure 5-3, Floor-Mounted Charging Station

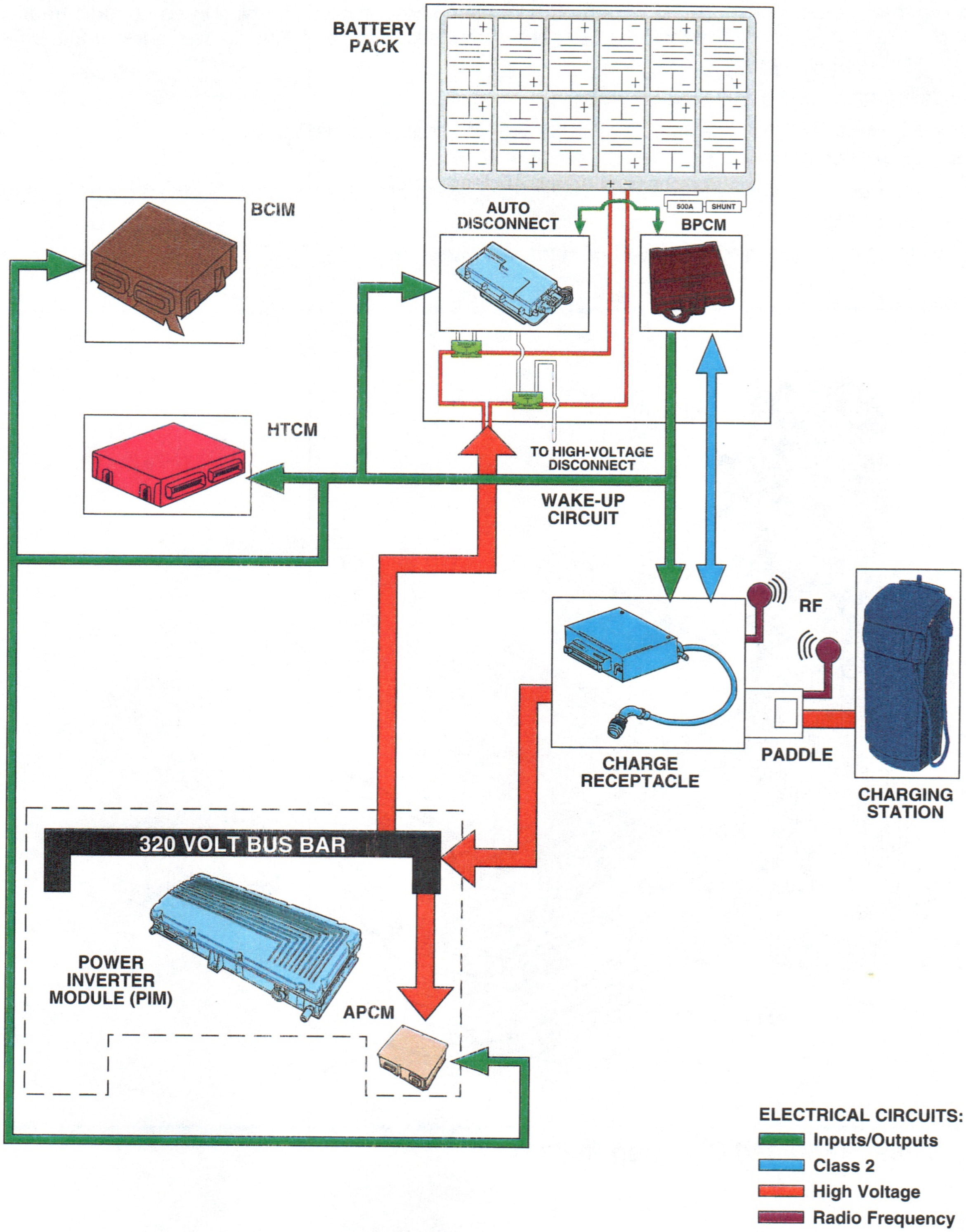

BATTERY PACK
BCIM
AUTO DISCONNECT
500A
SHUNT
BPCM
HTCM
TO HIGH-VOLTAGE DISCONNECT
WAKE-UP CIRCUIT
RF
CHARGE RECEPTACLE
PADDLE
CHARGING STATION
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟦 Class 2
🟥 High Voltage
🟪 Radio Frequency

Figure 5-4, Charging Wake-Up

Charging Wake-Up

When the charge paddle is inserted into the charge receptacle, the paddle forces the paddle-present switch closed. The charge receptacle sends a wake-up signal to the BPCM on the wake-up circuit when the paddle-present switch is closed. This signals the BPCM to begin the charging event. The BPCM then provides a "wake-up" voltage to the following control modules (refer to Figure 5-4):

- HTCM
- BCIM
- APCM
- Charge Receptacle
- Automatic Disconnect

The charge station paddle and the charge receptacle both contain a Radio Frequency (RF) antenna. These antennas are used for communication between the charge station and the charge receptacle. The RF antennas and the Class 2 data line (between the charge receptacle and the BPCM) allow the BPCM to communicate with the charging station. The BPCM will control the battery pack charging rate on this communication link with the charging station.

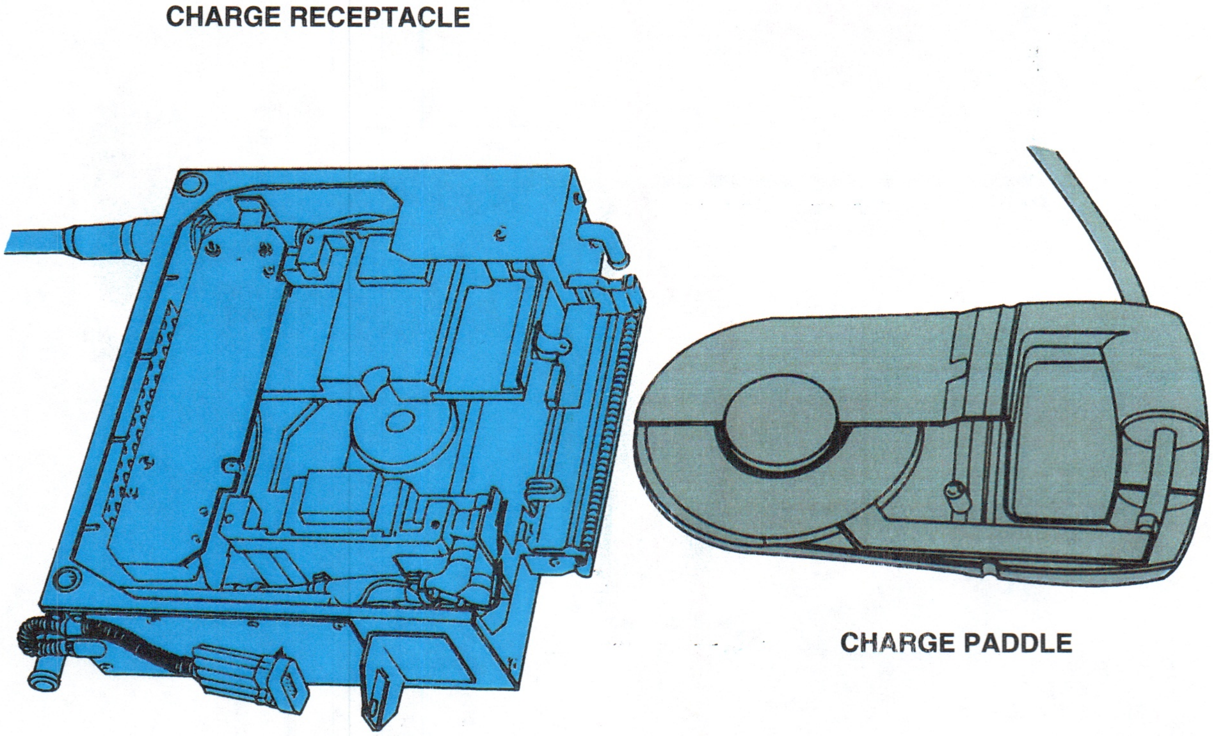


Figure 5-5, Charge Paddle and Charge Receptacle

5. Charging System Operation

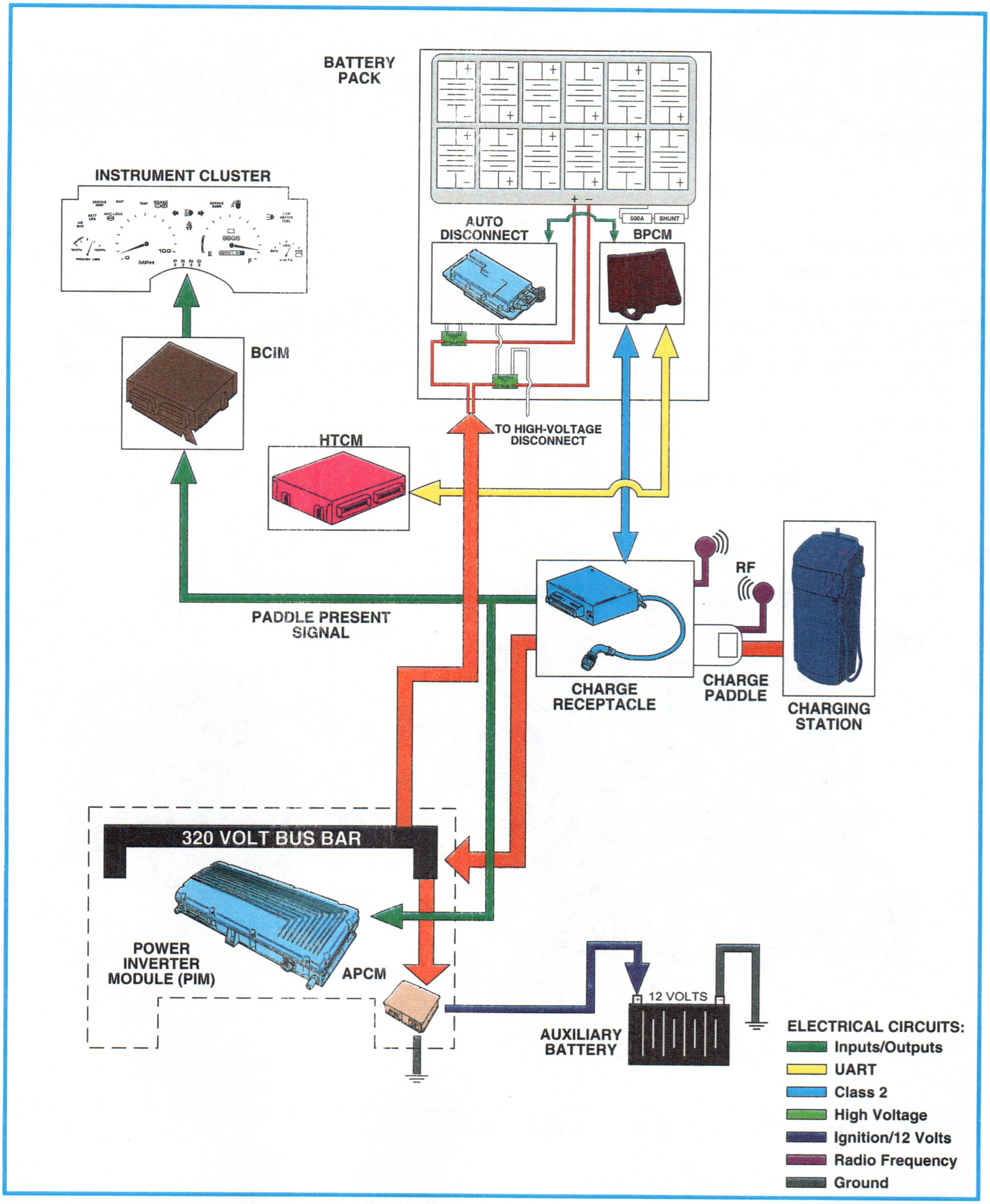

BATTERY PACK
INSTRUMENT CLUSTER
AUTO DISCONNECT
500A
SHUNT
BPCM
BCIM
HTCM
TO HIGH-VOLTAGE DISCONNECT
RF
CHARGE RECEPTACLE
CHARGE PADDLE
CHARGING STATION
PADDLE PRESENT SIGNAL
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Inputs/Outputs
UART
Class 2
High Voltage
Ignition/12 Volts
Radio Frequency
Ground

Figure 5-6, Battery Pack Charging Event

Figure 5-6 on the facing page applies to the 1997 Electric S10.

Notes

5. Charging System Operation (1998 Update)

In 1998, the discrete Paddle Present signal is sent only to the PIM. This signal will prevent the PIM from enabling propulsion. The Instrument Cluster receives the signal to illuminate the Paddle Present lamp from the Charge Receptacle on the Class 2 data line.

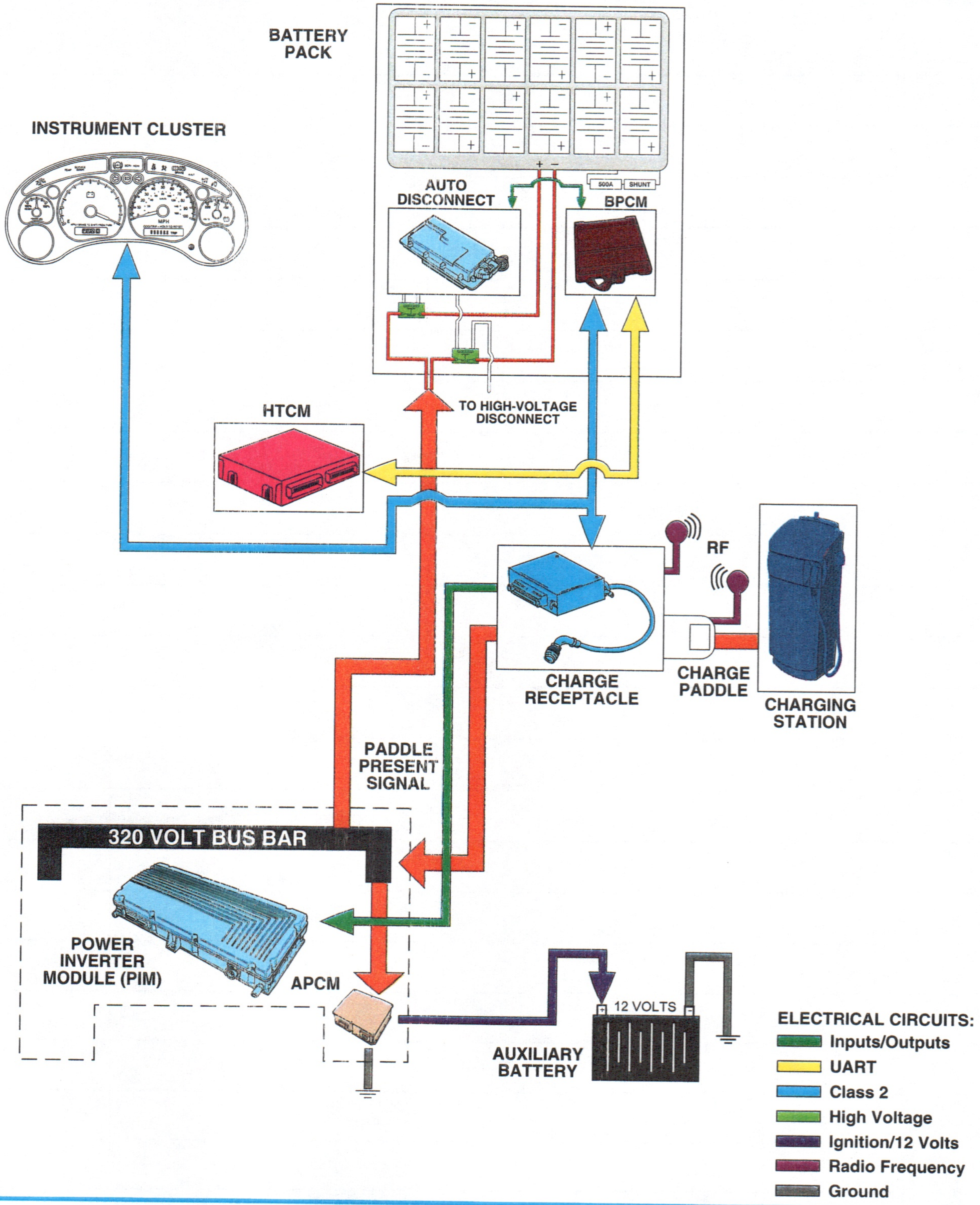

BATTERY PACK
INSTRUMENT CLUSTER
AUTO DISCONNECT
500A
SHUNT
BPCM
HTCM
TO HIGH-VOLTAGE DISCONNECT
RF
CHARGE RECEPTACLE
CHARGE PADDLE
CHARGING STATION
PADDLE PRESENT SIGNAL
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟦 Class 2
🟩 High Voltage
🟪 Ignition/12 Volts
🟥 Radio Frequency
⬛ Ground

Figure 5-6a, Battery Pack Charging Event

Charging

Once the BPCM provides the “wake-up” voltage to the charging system components, the BPCM will begin the charging event (refer to Figure 5-6). During the charging event, the BPCM will monitor the state-of-charge of each battery pack module and determine the charge rate. This charge rate will be communicated to the charging station. Certain malfunctions and conditions in the charging system will result in the BPCM inhibiting charging. For instance, the BPCM will not begin charging if the Transmission Range (TR) switch does not indicate the Park position.

Also during the charging event, the charge receptacle sends a paddle-present signal to the PIM and the BCIM. The signal to the PIM will prevent the PIM from enabling propulsion during a charging event. The paddle present signal to the BCIM will cause the BCIM to illuminate the PADDLE PRESENT lamp in the instrument cluster.

The charging station provides induction charging. There is not an electrical connection between the charging station paddle and the charge receptacle. The charging station creates an alternating magnetic field in the charge paddle (refer to Figure 5-7). This alternating magnetic field induces an alternating electrical current in the charge receptacle. This is similar to the operation of a transformer. The charge receptacle converts this Alternating Current (AC) into Direct Current (DC). The charge receptacle provides this current to the battery pack on the high voltage bus through the PIM.

The BPCM has the ability to request thermal management during the charging event if the battery pack temperature is outside of BPCM parameters. The thermal management request is sent to the HTCM on the UART data line. Refer to the Thermal Management System section for more information.

Also during the charging event, the APCM will charge the 12-volt auxiliary battery.

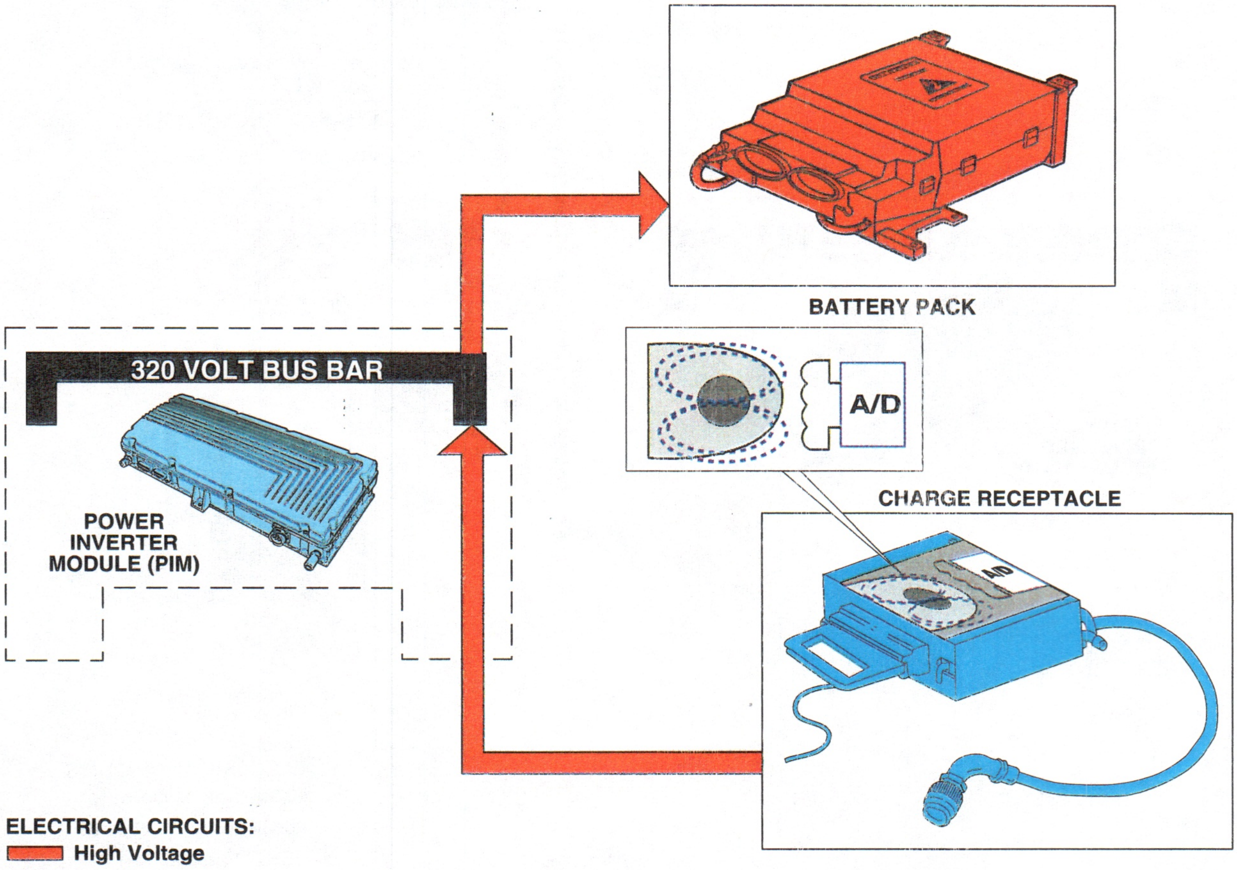


Figure 5-7, **Key Components for Charging**

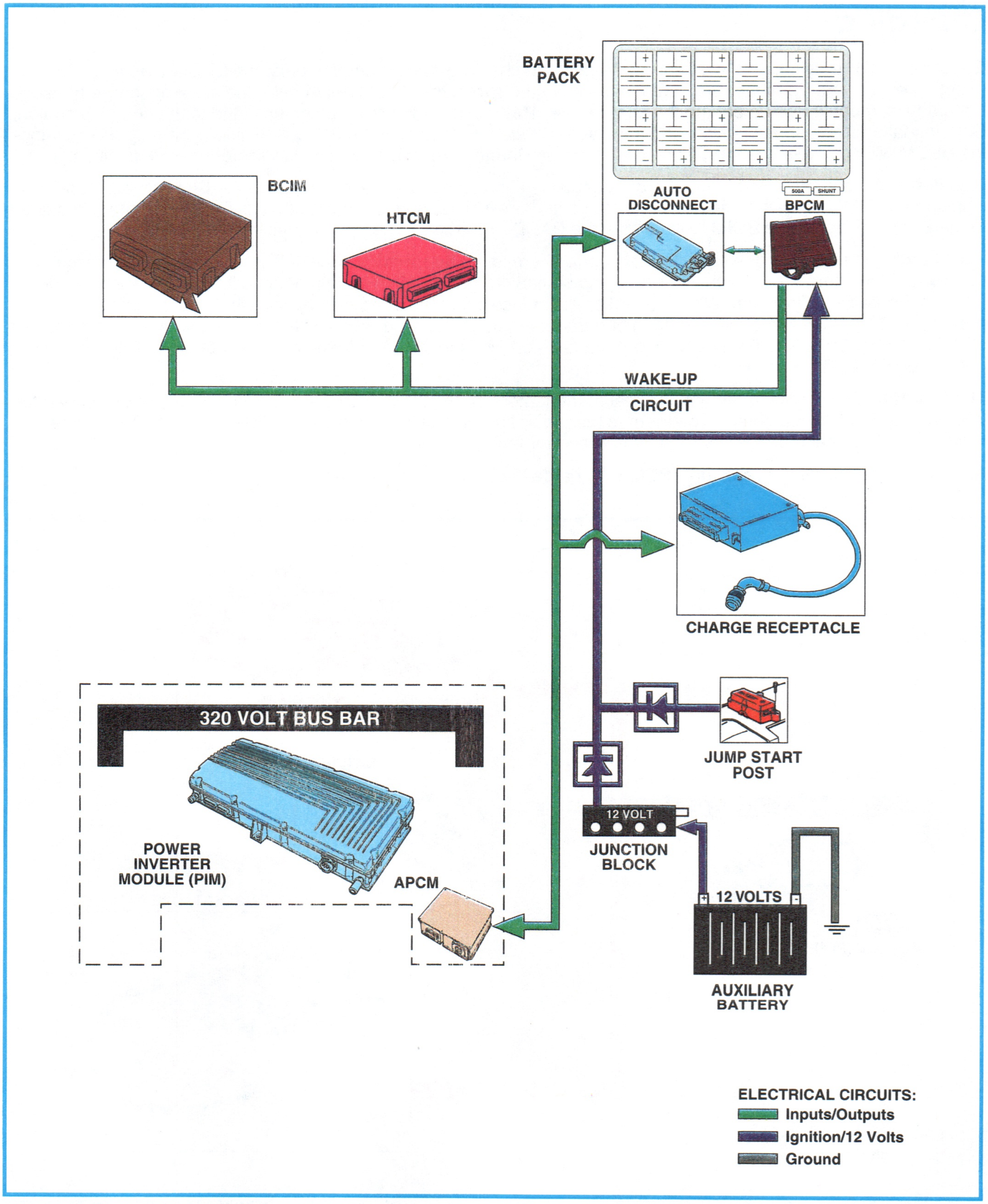

BATTERY PACK
500A
SHUNT
BCIM
HTCM
AUTO DISCONNECT
BPCM
WAKE-UP
CIRCUIT
CHARGE RECEPTACLE
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
JUMP START POST
12 VOLT
JUNCTION BLOCK
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Inputs/Outputs
Ignition/12 Volts
Ground

Figure 5-8, Jump Start

Jump Start

If the 12-volt auxiliary battery does not provide sufficient voltage, the BPCM will be unable to provide the "wake-up" voltage. If this occurs, both charging and propulsion will be disabled. To "wake" the system, 12 volts must be applied to the jump start post (refer to Figure 5-9). The ground of this voltage source must be connected to the chassis. The 12-volt battery must be connected during jump start. When voltage is applied to the jump start post, the BPCM will have sufficient voltage to provide the "wake-up" voltage (refer to Figure 5-8).

After power is applied to the jump start post, the BPCM can start the jump start charging event. Since the 12-volt auxiliary battery has insufficient voltage, the BPCM may have commanded the contactors in the battery pack to open. Before jump start charging can occur, the Auto Disconnect must slowly energize the high voltage circuit. This is done by providing a resistance in the high voltage circuit when the contactors are closed. This procedure is also called pre-conditioning. After the high voltage circuit energizes, the resistance is removed and the BPCM will start a normal charging event. During the jump start charging event, the APCM will charge the 12-volt auxiliary (accessory) battery.

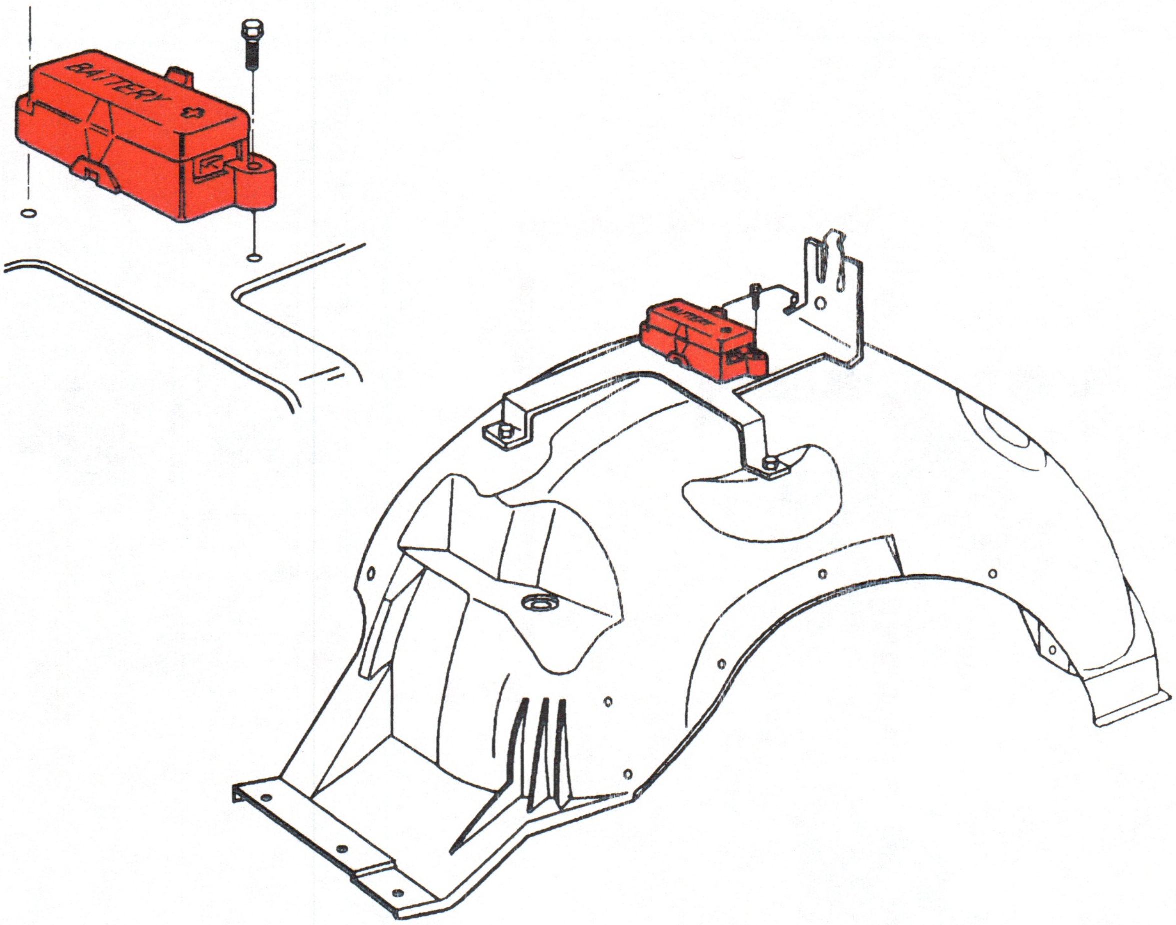


Figure 5-9, Jump Start Post

Regeneration (Regenerative Braking)

Regeneration is a method used to recharge the battery during vehicle coast. During regeneration, the wheels of the vehicle drive the rotor of the Drive Motor Unit (DMU) and induce an Alternating Current (AC) in the field windings. This alternating current is converted to direct current in the Power Inverter Module (PIM) and is used to recharge the 320-volt battery pack (refer to Figure 5-10).

The BPCM controls the amount of regeneration based on the battery pack state-of-charge. The BPCM will communicate the regeneration charging rate to the PIM on the UART data line.

If the BPCM indicates that regeneration can occur, the PIM will provide approximately 6% regeneration during a coast with the APP sensor indicating that the accelerator pedal is not depressed. If the brake switch is closed, the PIM will provide approximately 15% regeneration.

Since the rotor magnetic field must move through the magnetic field of the field winding, regeneration will provide resistance to the rotation of the rotor and wheels. This results in the vehicle slowing down during regeneration. This is similar to compression braking used in a gasoline powered vehicle. The amount of regeneration will normally determine the amount of resistance to rotor and wheel rotation.

The amount of regeneration is displayed on the REGEN Gauge in the instrument cluster.

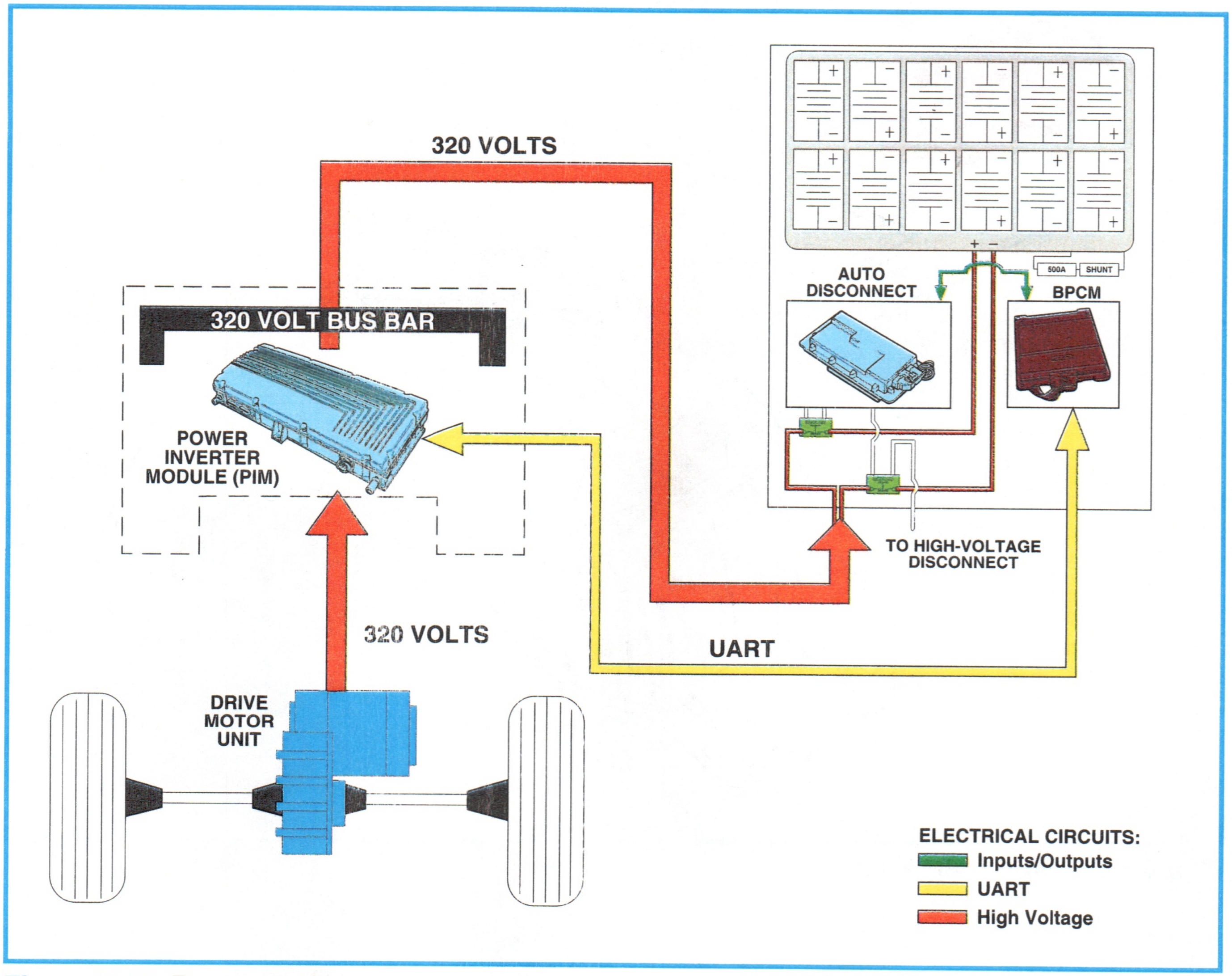

320 VOLTS
500A
SHUNT
AUTO DISCONNECT
BPCM
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
TO HIGH-VOLTAGE DISCONNECT
320 VOLTS
UART
DRIVE MOTOR UNIT
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage

Figure 5-10, Regeneration

6. Principles of Refrigeration

Introduction

Automotive air conditioning (A/C) systems are designed based on the laws of physics, chemistry, and electronics. A basic familiarity with these laws – together with an understanding of A/C components and their operation – provides the skills necessary for quick, accurate A/C system diagnosis.

Physics is the science of matter and energy. Simply put, it teaches us how things interact in our universe. Several laws of physics apply to automotive refrigerant systems:

- Behavior of heat
- Properties of liquids and gases
- Behavior of refrigerants (R-12 and R-134a)
- Effects of heat and pressure on liquids and gases

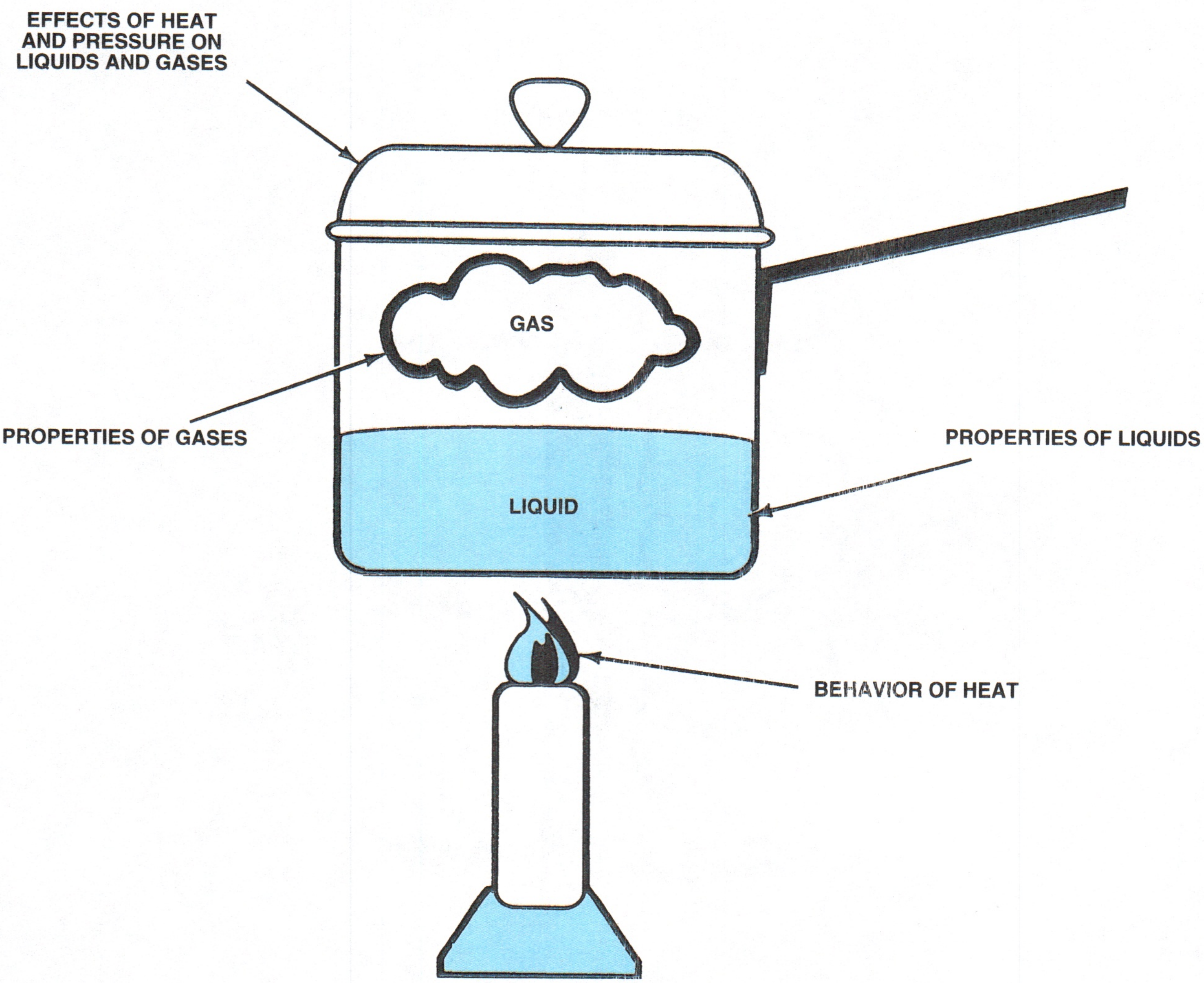

EFFECTS OF HEAT AND PRESSURE ON LIQUIDS AND GASES
GAS
PROPERTIES OF GASES
PROPERTIES OF LIQUIDS
LIQUID
BEHAVIOR OF HEAT

Figure 6-1, Principles Behind Automotive Air Conditioning Systems

Air Conditioning and Comfort

The sole purpose of an A/C system is for customer comfort. The A/C system achieves customer comfort by cooling the air temperature inside the passenger compartment and removing moisture (humidity), dust and pollen particles (see Figure 6-2).

By removing moisture and lowering the humidity, the A/C system can achieve customer comfort at higher temperatures. Laboratory tests show that people feel just as cool at 26°C (79°F) with 30% humidity as they do at 22°C (72°F) with 90% humidity. The reason for this is that the human body cools itself by allowing moisture on the skin to evaporate. When the moisture evaporates it cools the skin.

The relative humidity governs how quickly evaporation occurs:

- High relative humidity = low evaporation rate.
- Low relative humidity = high evaporation rate.

When the A/C system removes moisture from the air, the relative humidity in the passenger compartment decreases. By reducing the relative humidity, the A/C system increases the rate at which the moisture on passengers' skin will evaporate.

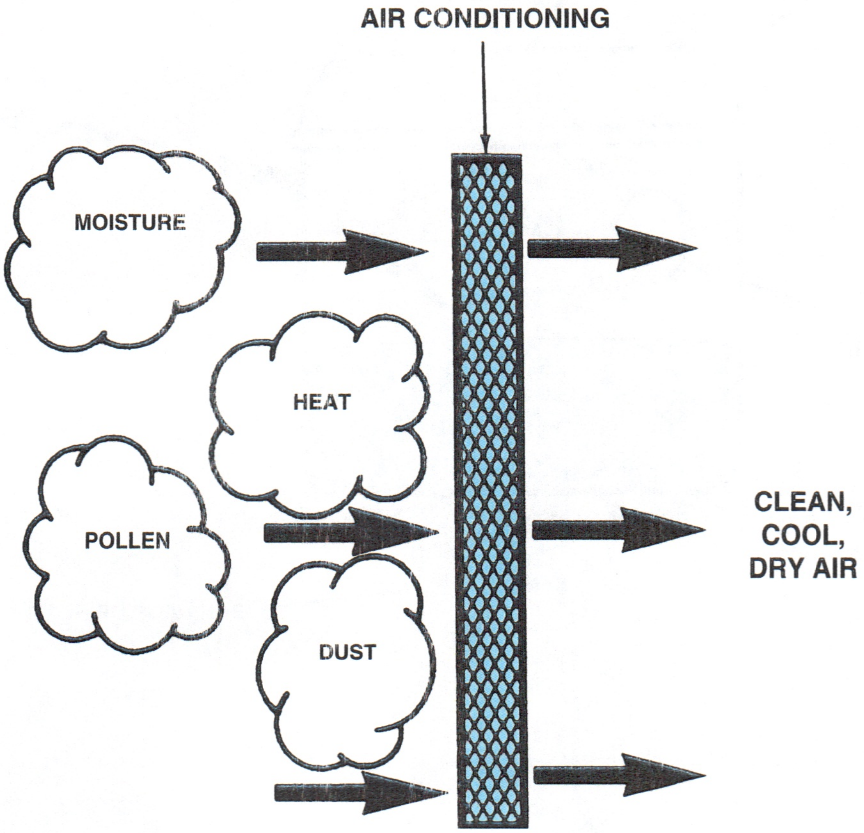


Figure 6-2, **Functions of the A/C System**

Heat Versus Temperature

A/C systems operate by removing heat from the air entering the passenger compartment. The result of this is a lower temperature. Temperature and heat are not interchangeable terms.

Heat is the energy in a substance. Heat can be measured by British Thermal Units (BTUs). One BTU is the amount of heat needed to raise one pound of water one degree Fahrenheit at sea level. Heat is independent of temperature. The cup of coffee and the coffee pot in Figure 6-3 are both the same temperature but have different amounts of heat.

Temperature is the intensity level of the heat. Temperature can be measured in degrees Celsius (C) and degrees Fahrenheit (F). An object that is hot has a high intensity of heat. An object that is cold has a low intensity of heat. Cold objects have heat but a lower intensity level of heat. In Figure 6-4, the cold pool has a greater quantity of heat than the hot barbecue even though the barbecue has a much higher intensity of heat.

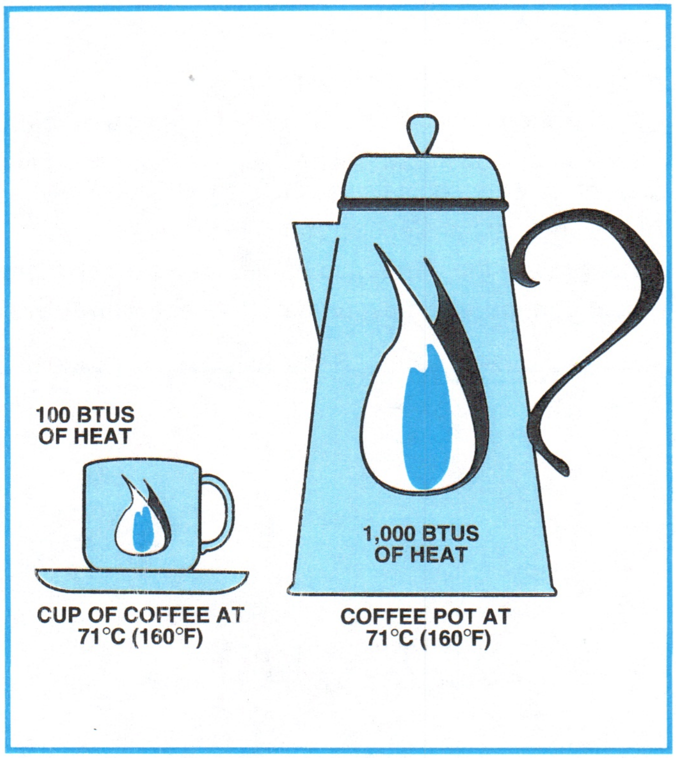


Figure 6-3, Temperature Versus Energy

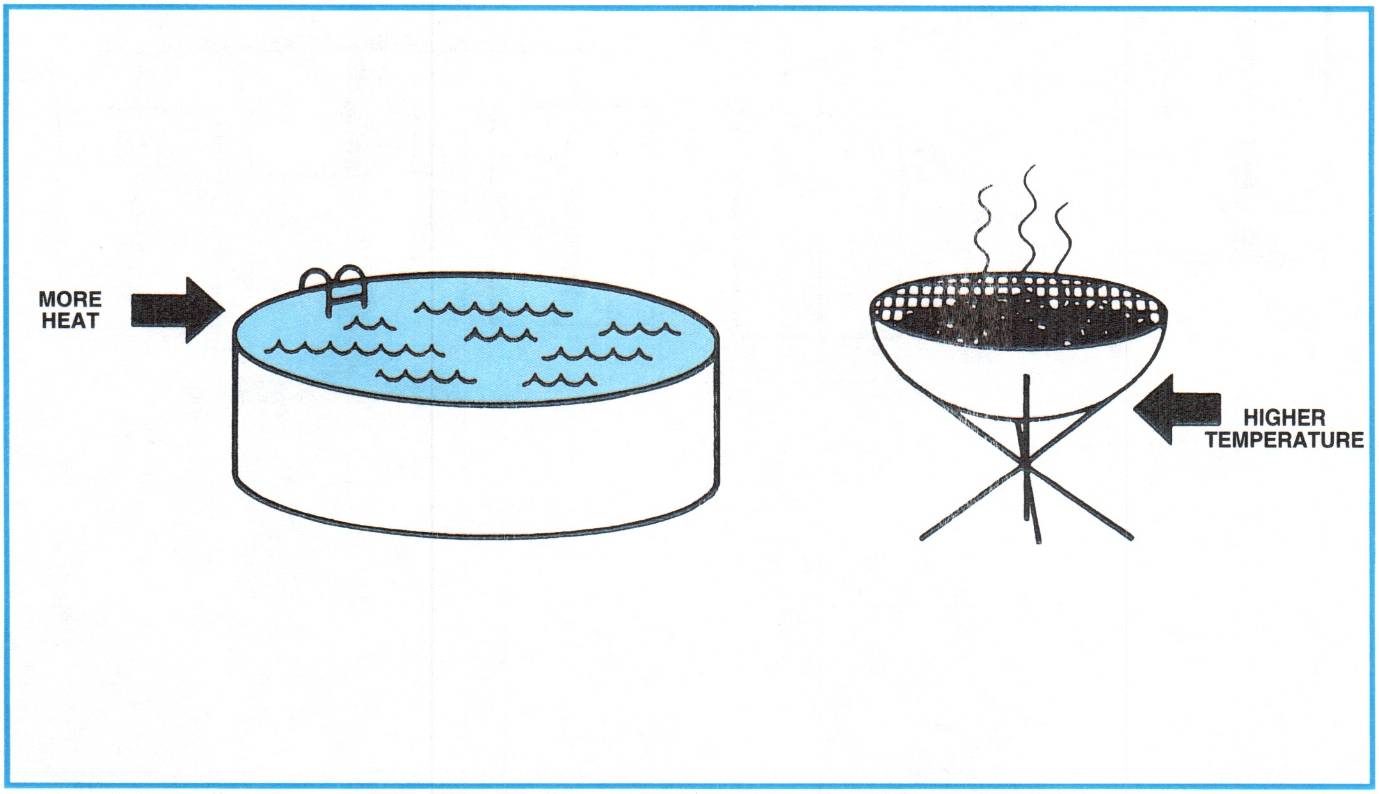


Figure 6-4, Heat Versus Temperature

Heat Transfer

The law of heat transfer states that:

- **Heat always flows from an area of higher temperature to an area of lower temperature.**

Just as water flows downhill, heat always flows down the temperature scale (see Figure 6-5). Thus, when holding a glass of ice water, heat flows from the warm hand to the cooler glass.

The law of heat transfer also states that:

- **The greater the difference in temperature, the faster heat flows.**
- **Heat continues to flow until both temperatures are equal (heat transfer tries to equalize intensity).**

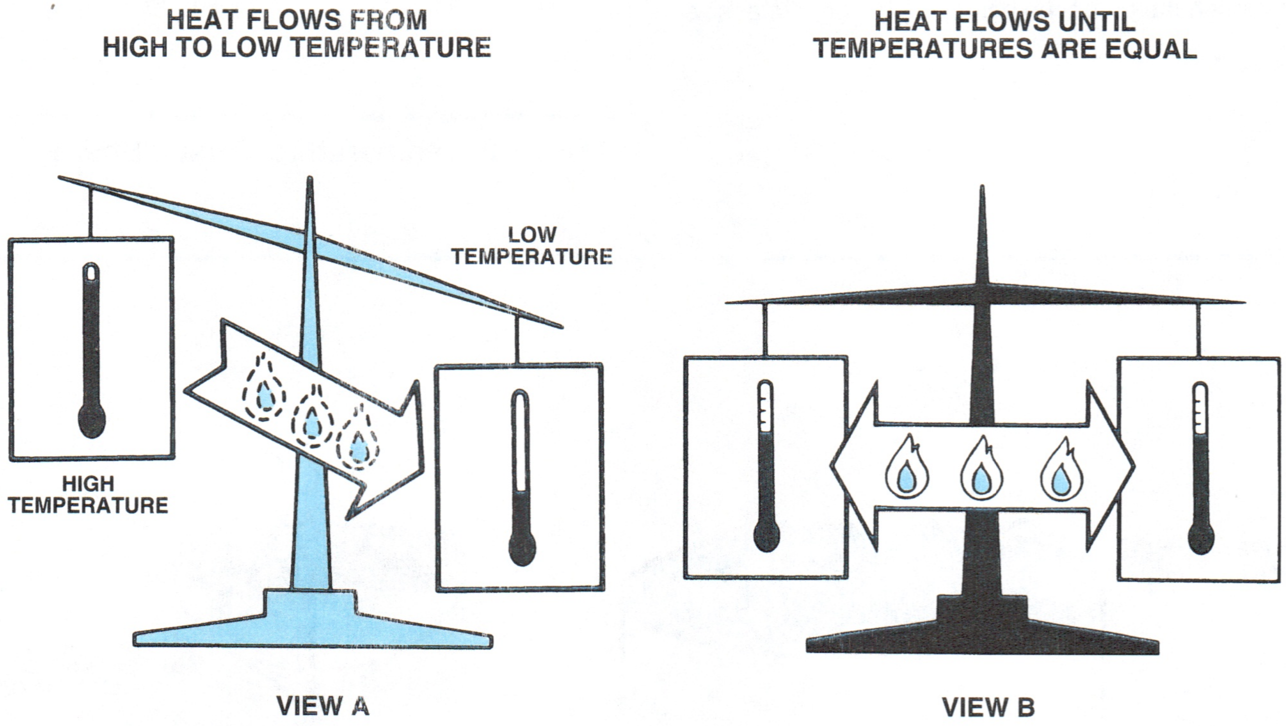

HEAT FLOWS FROM
HIGH TO LOW TEMPERATURE
LOW
TEMPERATURE
HIGH
TEMPERATURE
VIEW A
HEAT FLOWS UNTIL
TEMPERATURES ARE EQUAL
VIEW B

Figure 6-5, Heat Transfer Equalizes Temperature

An automotive engine cooling system is an excellent example of the different types of heat transfer: conduction, convection, and radiation. The heat transfer process occurs throughout the system (see Figure 6-6).

Inside the engine cylinders, burning fuel generates tremendous amounts of heat. However, because engine coolant keeps the cylinder walls cooler than the temperature of the burning fuel, heat flows from the combustion gases to the cooler inner cylinder wall. This heat is then transferred to the outer cylinder wall and to the liquid coolant. The outer cylinder wall is hotter than the coolant, so heat flows to the lower-temperature coolant. This type of heat flow is called "conduction" – the flow of heat through a substance.

The water pump circulates the heat-saturated coolant away from the cylinder walls to the radiator. This movement of heat from one place to another using a liquid transfer path is known as "convection."

Conductive transfer again occurs at the radiator, where the heat energy moves to the cooler radiator surfaces. Then, as air flows through the radiator core, the heat radiates to the cooler air.

The law of heat transfer, along with the design of the cooling system, prevent engine overheating. Each time heat flows, the law is upheld: Heat flows from areas of higher temperature to areas of lower temperature.

In principle, an air conditioning system does the same job as an engine cooling system. An engine cooling system carries heat away from the engine via coolant, while the A/C system carries heat away from air in the passenger compartment via refrigerant. Both systems release stored heat to the outside air.

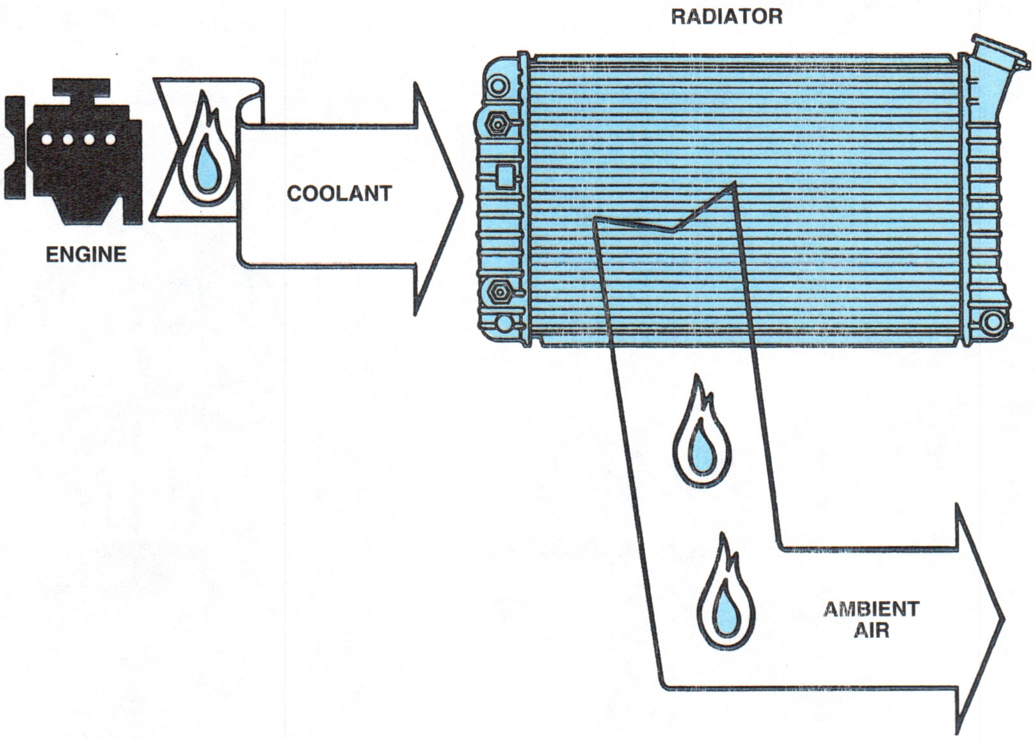


Figure 6-6, Heat Transfers in an Engine Cooling System

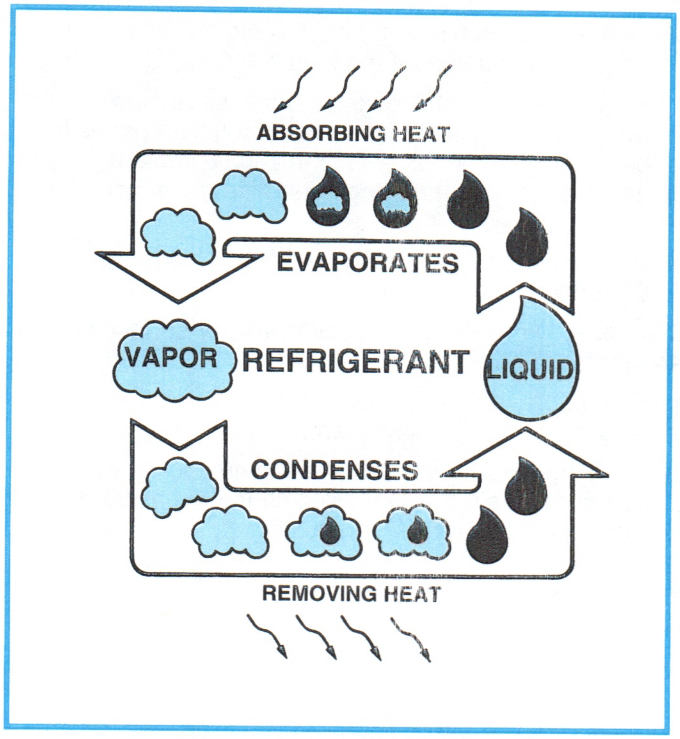


Figure 6-7, Refrigerant Changes States

States of Matter

Because the A/C refrigeration system and the engine cooling systems use different mediums for heat transfer, there are some important differences between the two systems.

Engine coolant is an ethyl glycol-based liquid. Ideally, it remains a liquid as it transfers heat. Refrigerant, on the other hand, evaporates and condenses each time it absorbs and transfers heat. As a result, it changes from a liquid to a vapor and back to a liquid as it flows through the A/C system (see Figure 6-7).

In physics, a change in state occurs when the molecular structure of a substance is rearranged as it changes between any two of the three physical states: solid, liquid, or gas (see Figure 6-8). For example, an ice cube is a solid. Yet, when dropped onto a hot griddle, the ice undergoes a change of state as it melts into a liquid. And, as the water evaporates into a vapor, another change of state occurs.

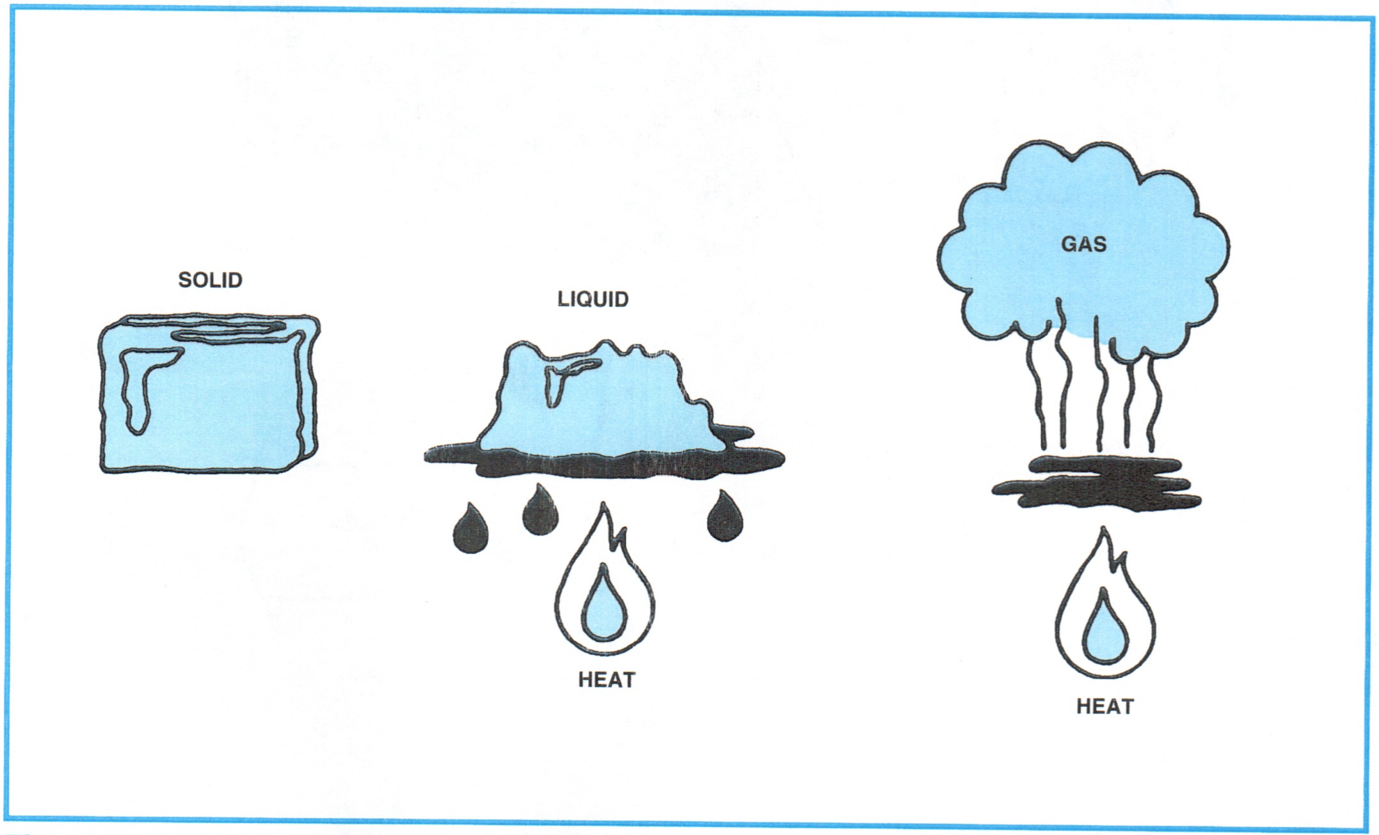


Figure 6-8, Changes in States of Matter

Latent Heat and the Vaporization of Liquids

Another law of physics is the heat of vaporization law. It states:

- **A specific amount of heat is needed to change a liquid into a vapor.**

The amount of heat needed to change one gram of liquid into a vapor is called its heat of vaporization. The heat of vaporization is also known as **latent heat**. Latent heat refers to the heat absorbed as the liquid changes state. It is called latent (hidden) heat because, even though a lot of heat is absorbed as a change in state occurs, the liquid and vapor remain at the same temperature (see Figure 6-9).

When water has absorbed enough heat to boil, it turns to vapor. Water at 100°C (212°F) turns into vapor at the same temperature. Under normal circumstances, adding more heat to the water does not increase the temperature of the water. Boiling water at atmospheric pressure (101.4 kPa/14.7 psi) cannot be heated above 100°C (212°F). Any heat above the quantity necessary to boil water only produces greater quantities of vapor in less time.

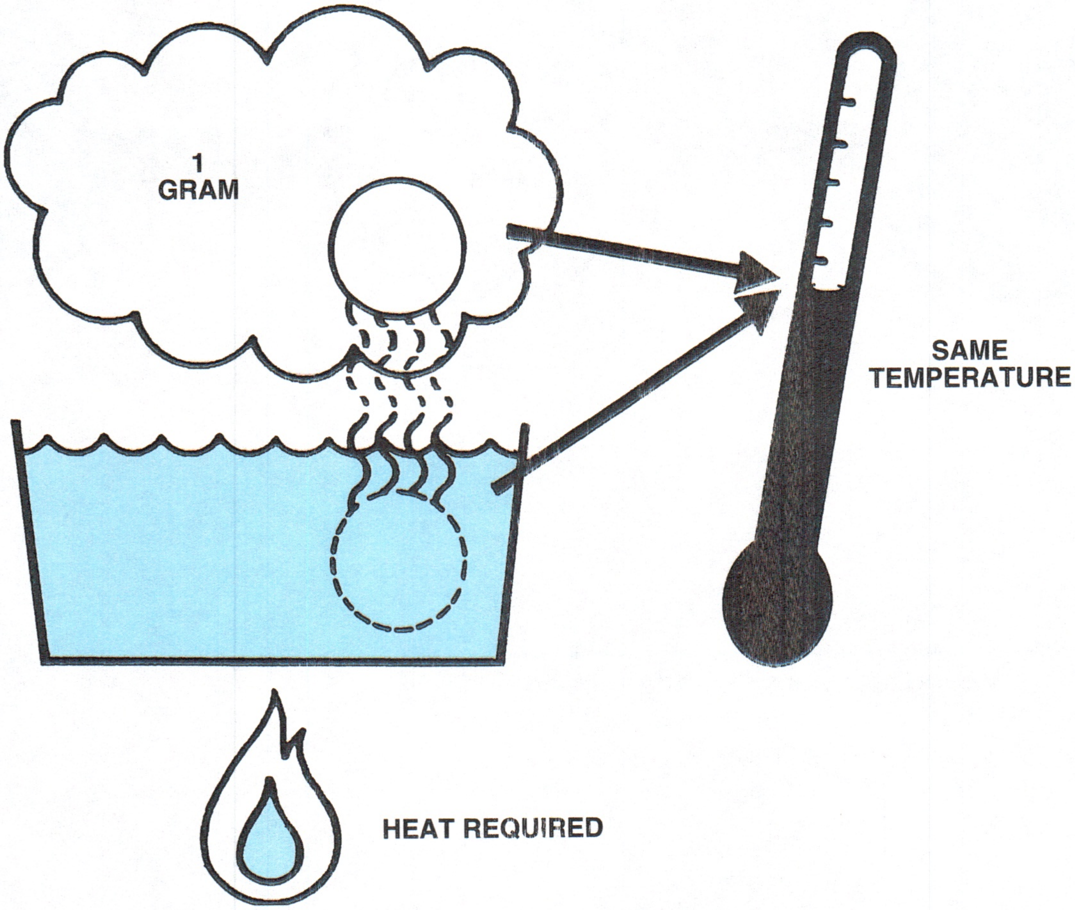


Figure 6-9, **Heat of Vaporization**

When vapor changes to liquid, it is said to "condense." A common example of condensation is found on the bathroom mirror during a steamy shower. Moisture from the steamy air condenses as it comes in contact with the cool mirror. This moisture collects on the mirror and drips down the surface in the form of a liquid.

When vapor condenses, it releases its latent heat (see Figure 6-10). The latent heat of condensation is the amount of heat released as vapor changes to a liquid.

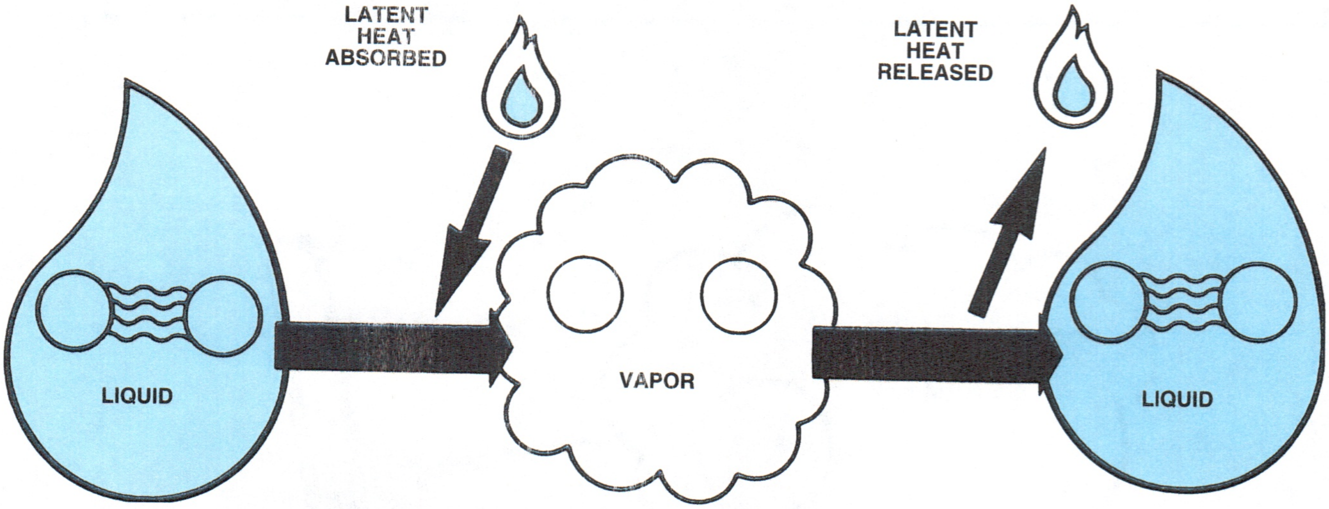

LATENT HEAT ABSORBED
LATENT HEAT RELEASED
LIQUID
VAPOR
LIQUID

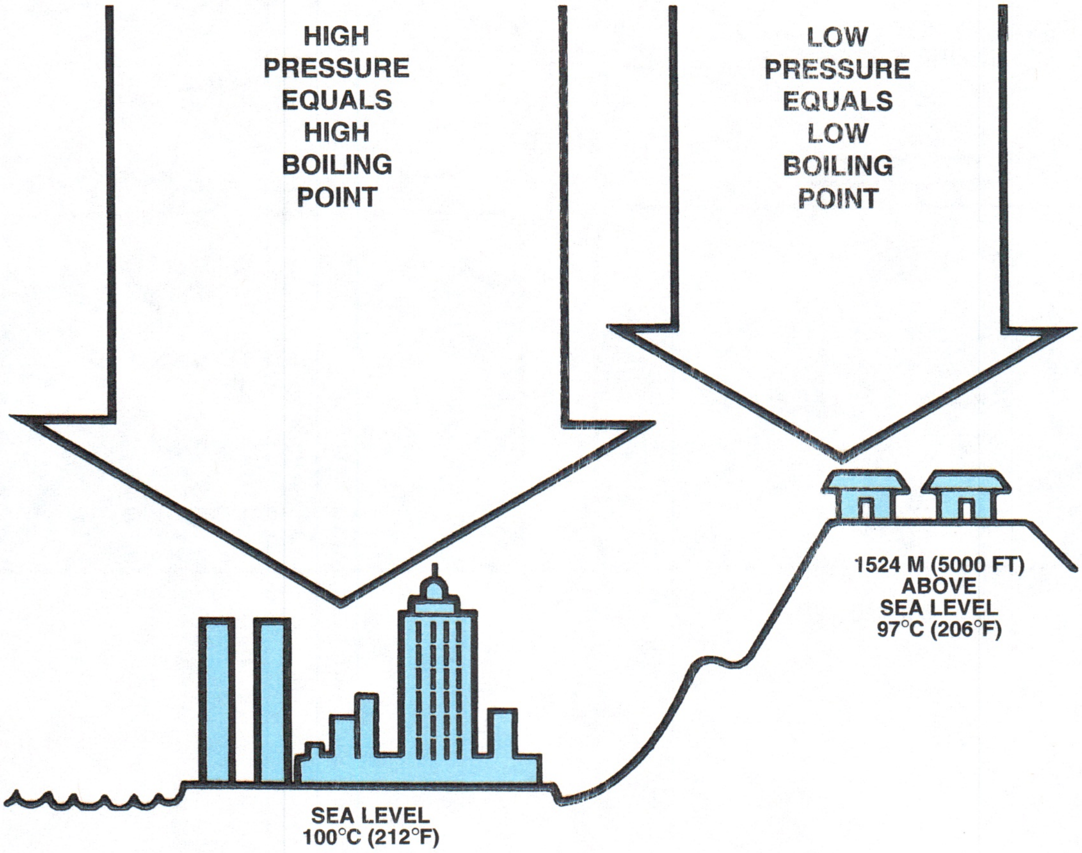
Figure 6-10, **Vaporization and Condensation**

Pressure-Temperature Relationships

The science of physics includes laws describing the relationship between pressure and the boiling points of liquids:

- **If the pressure acting on a liquid is increased, the boiling point of the liquid increases** (see Figure 6-11).
- **Lowering the pressure acting on a liquid lowers its boiling point.**

Thus, water in a vacuum boils at a very low temperature, while water in a pressurized engine cooling system boils at well above 100°C (212°F).


HIGH PRESSURE EQUALS HIGH BOILING POINT
LOW PRESSURE EQUALS LOW BOILING POINT
1524 M (5000 FT) ABOVE SEA LEVEL 97°C (206°F)
SEA LEVEL 100°C (212°F)

LATENT HEAT EXCHANGE IS THE SAME AMOUNT AT BOTH ALTITUDES, BUT WATER TURNS TO STEAM AT DIFFERENT TEMPERATURES.

Figure 6-11, Effect of Pressure on Boiling Point

An engine cooling system readily demonstrates the effect of pressure on the boiling point of water. As water in the cooling system warms up, pressure builds in the sealed system. This pressure increases the boiling point of the water well above 100°C (212°F). As long as the system remains sealed and pressure is maintained, the water can be heated above its normal boiling point without boiling (see Figure 6-12, View A).

However, if the radiator cap is removed, the pressure in the cooling system is released. This means the pressure acting on the water is now ambient air pressure. The water, heated under pressure to more than 100°C (212°F), will boil as soon as the pressure is released (see Figure 6-12, View B).

This example is useful, as pressure affects all liquids the same way it affects water.

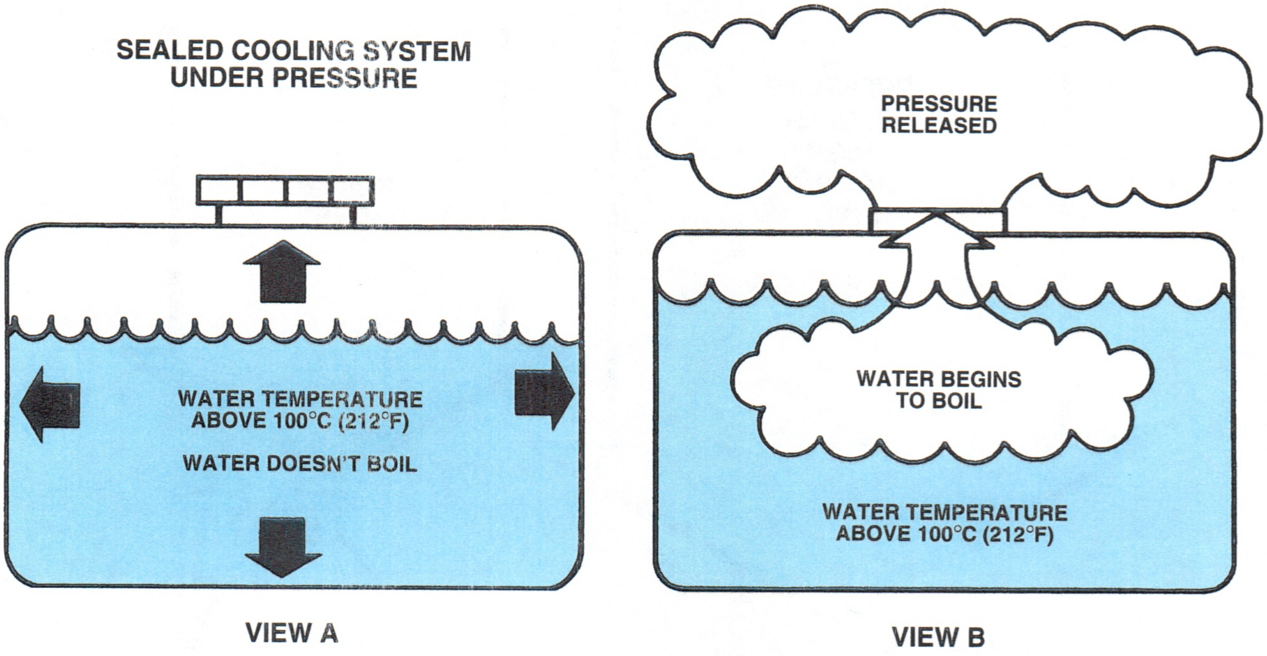

SEALED COOLING SYSTEM
UNDER PRESSURE
WATER TEMPERATURE
ABOVE 100°C (212°F)
WATER DOESN'T BOIL
VIEW A
PRESSURE
RELEASED
WATER BEGINS
TO BOIL
WATER TEMPERATURE
ABOVE 100°C (212°F)
VIEW B

Figure 6-12, **Boiling Point in a Sealed and Open System**

Effect of Pressure on Gases and Vapors

Pressure also affects the temperature of gases and vapors. Compressing a gas or vapor increases its temperature, because the same amount of heat is concentrated into a smaller area (see Figure 6-13). Thus, the temperature of the gas or vapor can be increased without adding extra heat. This is what happens inside an A/C compressor.

A compressor uses pressure to concentrate the heat of a vapor. A heat transfer occurs when the vapor contacts a cooler surface. Transferring heat away from the hot, high-pressure vapor condenses it into a liquid. Lowering the pressure of this liquid causes it to boil and absorb heat as it changes states.

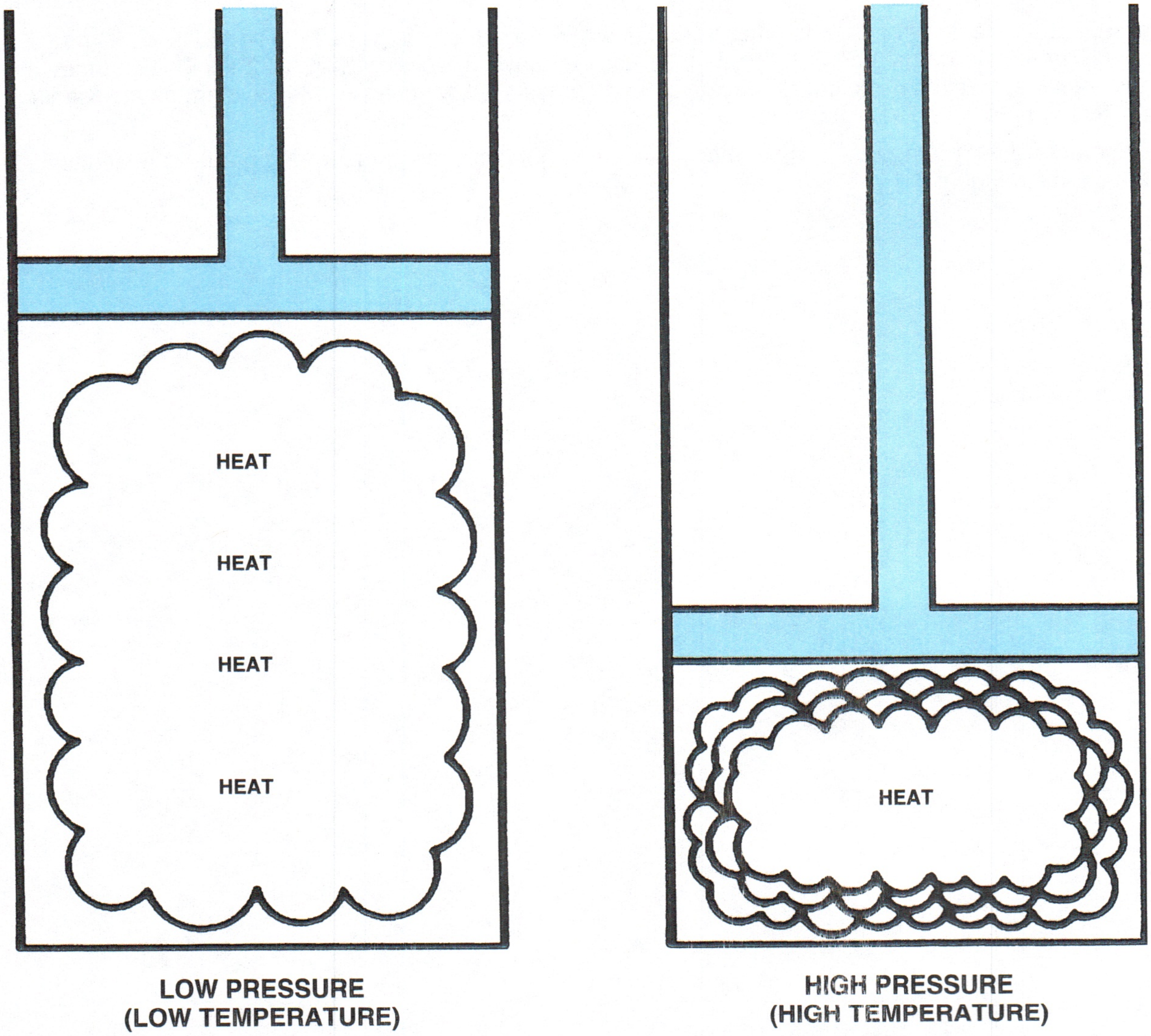

HEAT
HEAT
HEAT
HEAT
HEAT
LOW PRESSURE
(LOW TEMPERATURE)
HIGH PRESSURE
(HIGH TEMPERATURE)

Figure 6-13, **Concentrating Heat Raises Temperature**

A/C System Temperature-Pressure Relationships

Pressure in an A/C system raises the boiling point of the refrigerant. Thus, automotive A/C systems are designed to operate at pressures that keep the boiling point of refrigerant at just the right temperature for taking heat out of the passenger compartment.

A definite temperature and pressure relationship exists between liquid refrigerants and their vapors. Heating refrigerant causes it to expand. When confined in a closed space, an increase in temperature is always accompanied by an increase in pressure – even though no compressor is present.

For every temperature increase, a corresponding pressure will exist in a container of R-12 or R-134a. Figure 6-14 shows this temperature-pressure relationship. Pressures are expressed either as positive gauge pressure (above atmospheric, in kPa [psi]), or negative gauge pressure (below atmosphere, inches of vacuum).

This temperature-pressure relationship can be easily demonstrated. A pressure gauge attached to a container of R-12 at 21°C (70°F) reveals a pressure of about 484 kPa (70 psi). At 38°C (100°F), the gauge will register about 808 kPa (117 psi).

The pressure characteristics of R-134a differ from those of R-12. The boiling point of R-134a is -27°C (-16°F) at sea level (101.4 kPa [14.7 psi]) or 3°C (6°F) higher than R-12, which boils at -30°C (-22°F). This changes the temperature-pressure relationship curve. Because of this pressure difference, R-134a system gauge readings will differ slightly from previous R-12 systems.

If the refrigerant within a refrigeration system or container is not pure, the pressure-temperature relationship will not match the charts in Figure 6-14.

R-134a AUTOMOTIVE

R-134a TEMPERATURE-PRESSURE CHART

TEMPERATURE °C (°F)		PRESSURE kPa (PSI)	TEMPERATURE °C (°F)		PRESSURE kPa (PSI)
-9 (16)		106 (15)	38 (100)		857 (124)
-8 (18)		115 (17)	39 (102)		887 (129)
-7 (20)		124 (18)	40 (104)		917 (133)
-6 (22)	EVAPORATOR RANGE	134 (19)	41 (106)		948 (137)
-4 (24)		144 (21)	42 (108)		980 (142)
-3 (26)		155 (22)	43 (110)	CONDENSER RANGE	1012 (147)
-2 (28)		166 (24)	44 (112)		1045 (152)
-1 (30)		177 (26)	46 (114)		1079 (157)
0 (32)		188 (27)	47 (116)		1114 (162)
1 (34)		200 (29)	48 (118)		1149 (167)
2 (36)		212 (31)	49 (120)		1185 (172)
3 (38)		225 (33)	50 (122)		1222 (177)
4 (40)		238 (35)	51 (124)		1260 (183)
7 (45)		272 (40)	52 (126)		1298 (188)
10 (50)		310 (45)	53 (128)		1337 (194)
13 (55)		350 (51)	54 (130)		1377 (200)
16 (60)		392 (57)	57 (135)		1481 (215)
18 (65)		438 (64)	60 (140)		1590 (231)
21 (70)		487 (71)	63 (145)		1704 (247)
24 (75)		540 (78)	66 (150)		1823 (264)
27 (80)		609 (88)	68 (155)		1948 (283)
30 (85)		655 (95)	71 (160)		2079 (301)
32 (90)		718 (104)	74 (165)		2215 (321)
35 (95)		786 (114)	77 (170)		2358 (342)

R-12 AUTOMOTIVE

R-12 TEMPERATURE-PRESSURE CHART

TEMPERATURE °C (°F)		PRESSURE kPa (PSI)	TEMPERATURE °C (°F)		PRESSURE kPa (PSI)
-9 (16)		127 (18)	38 (100)		808 (117)
-8 (18)		136 (20)	39 (102)		833 (121)
-7 (20)		145 (21)	40 (104)		859 (125)
-6 (22)	EVAPORATOR RANGE	155 (22)	41 (106)		893 (129)
-4 (24)		165 (24)	42 (108)		917 (133)
-3 (26)		175 (25)	43 (110)	CONDENSER RANGE	940 (136)
-2 (28)		185 (27)	44 (112)		969 (140)
-1 (30)		196 (28)	46 (114)		997 (145)
0 (32)		207 (30)	47 (116)		1027 (149)
1 (34)		219 (32)	48 (118)		1057 (153)
2 (36)		230 (33)	49 (120)		1087 (158)
3 (38)		249 (36)	50 (122)		1118 (162)
4 (40)		255 (37)	51 (124)		1150 (167)
7 (45)		287 (42)	52 (126)		1182 (171)
10 (50)		322 (47)	53 (128)		1215 (176)
13 (55)		359 (52)	54 (130)		1248 (181)
16 (60)		398 (58)	57 (135)		1334 (194)
18 (65)		440 (64)	60 (140)		1425 (207)
21 (70)		484 (70)	63 (145)		1519 (220)
24 (75)		531 (77)	66 (150)		1618 (235)
27 (80)		580 (84)	68 (155)		1721 (250)
30 (85)		633 (92)	71 (160)		1828 (265)
32 (90)		688 (100)	74 (165)		1940 (281)
35 (95)		746 (108)	77 (170)		2057 (298)

EVAPORATOR PRESSURES REPRESENT GAS TEMPERATURES INSIDE THE COIL AND NOT THE COIL SURFACES. ADD TO TEMPERATURE FOR COIL AND AIR-OFF TEMPERATURES (4 TO 6°C/8 TO 10°F).

CONDENSER TEMPERATURES ARE NOT AMBIENT TEMPERATURES. ADD TO AMBIENT (19 TO 22°C/35 TO 40°F) FOR PROPER HEAT TRANSFER, THEN REFER TO CHART.

EXAMPLE:

32°C
+22°
54°C CONDENSER TEMPERATURE = 1377 KPA (R-134a) OR 1248 KPA (R-12) BASED ON 30 MPH AIRFLOW

CONDITIONS WILL VARY FOR DIFFERENT SYSTEM CONFIGURATIONS.
REFER TO MANUFACTURER'S SPECIFICATIONS.

Figure 6-14, Temperature-Pressure Relationships (Approximate)

Basic Refrigeration Cycle

Automotive A/C systems move heat from one place to another by compressing, condensing, and evaporating refrigerant. The A/C system creates these special conditions by using pressure and heat transfer to control the changing states of liquid and vapor.

An A/C refrigerant system consists of several components connected together with tubing and hoses to form a closed loop for the refrigeration cycle. Refrigerant flows through the closed loop, absorbing heat in the evaporator and releasing it in the condenser.

All automotive A/C systems contain these components (see Figure 6-15):

- **Compressor** – uses pressure to concentrate refrigerant vapor's heat.
- **Condenser** – transfers heat away from vapor coming out of compressor, condensing the refrigerant into liquid.
- **Evaporator** – transfers heat from passenger compartment air to the refrigerant, vaporizing the refrigerant.
- **Refrigerant** – absorbs and releases heat as it changes states.
- **Lubricant** – extends compressor life.

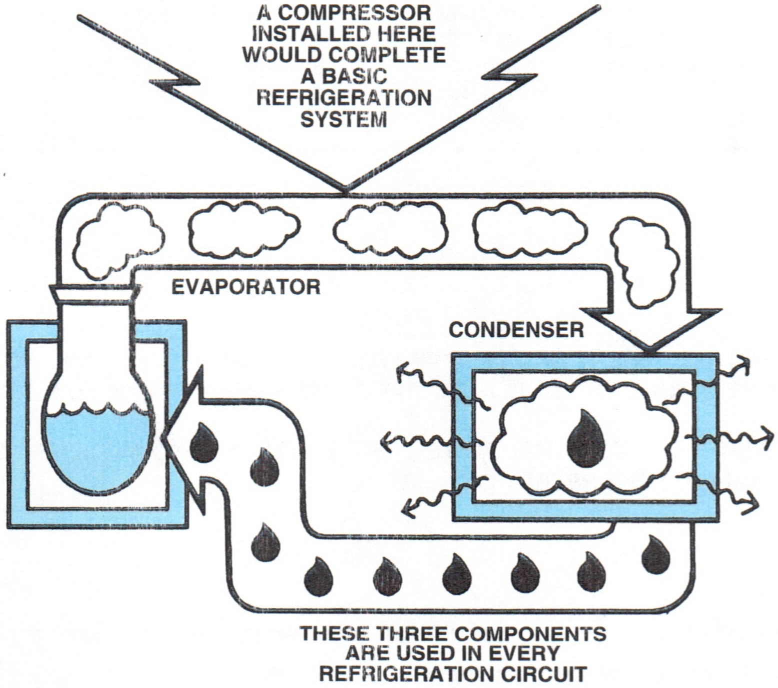

A COMPRESSOR INSTALLED HERE WOULD COMPLETE A BASIC REFRIGERATION SYSTEM
EVAPORATOR
CONDENSER
THESE THREE COMPONENTS ARE USED IN EVERY REFRIGERATION CIRCUIT

Figure 6-15, **Basic Refrigeration Cycle**

Controlling Refrigerant in the A/C System

Pressure and Flow

In addition to the compressor, condenser, and evaporator, A/C systems require some method of controlling refrigerant pressure and flow. The compressor can pump refrigerant vapor through the system. But unless it has something to push against, it cannot build up system pressure and maintain the conditions necessary to achieve the refrigeration effect.

Refrigerant system pressure is necessary. Low-side system pressure keeps the boiling point of the refrigerant at the proper level. High evaporator pressure would slow the evaporization of refrigerant and reduce the refrigeration effect. High-side system pressure allows the refrigerant to condense at normal ambient temperatures.

A metering device is used to help the compressor build pressure and maintain the refrigerant cycle. GM uses two types of metering devices: orifice tubes and thermostatic expansion valves (TXV). Orifice tubes have openings of fixed diameters for metering refrigerant flow. TXVs vary refrigerant flow based on evaporator outlet temperatures.

High- and Low-Pressure Areas

The refrigerant system is divided into two portions: a high-pressure area (high side) and a low-pressure area (low side) (see Figure 6-16). These two areas are separated by a metering device (orifice tube or TXV) and compressor.

Because the compressor can move more refrigerant than is able to pass through the metering device in a given time, pressure builds between the compressor outlet and the metering device. Therefore, the high side of the refrigerant system extends from the compressor outlet, through the condenser, to the metering device inlet. During operation, the high-pressure side is also the high-temperature side of the system.

The low side starts at the metering device outlet, includes the evaporator and accumulator, and continues to the compressor inlet. During operation, the low-pressure side is also the low-temperature side of the refrigerant system.

The high- and low-pressure sides can be distinguished in several ways:

- **Tube diameter** – High-side tubing is often smaller than low-side tubing.
- **Feel** – High-side tubing is hotter than low-side tubing.
- **Sight** – Low-side tubing is often cool enough to collect frost or water droplets on high-humidity days.
- **Pressure** – A gauge set can be used to measure the pressures in an A/C system.
- **Refrigerant temperature** – Various methods can be used to determine refrigerant temperature.

Inside an operating A/C system, the following process continuously occurs:

- Low-pressure refrigerant vapor is drawn into the compressor. During compression, this vapor becomes a hot, high-pressure vapor.
- The hot, high-pressure vapor then passes into the condenser. Here, the vapor transfers its heat to the condenser surfaces.
- As the refrigerant vapor gives up its heat, it condenses and cools into a high-pressure liquid.
- The high-pressure liquid passes through a restriction (orifice tube or TXV) into the evaporator. The restriction controls the volume of refrigerant entering the low-pressure side of the system.
- Inside the evaporator, the low-pressure refrigerant begins to vaporize as it soaks up heat from the evaporator surfaces. This refrigerant vapor collects in the accumulator, which acts as a storage tank.
- As the refrigerant vaporizes, it expands and increases low-side pressure. This refrigerant vapor is drawn into the compressor, and the cycle repeats.

Controlling Refrigerant Flow

Depending on design, automotive A/C systems use several methods to control the flow of refrigerant. Central to each design, however, is the continuous interaction of the compressor with a flow control device, such as an orifice tube. The volume of flow is adjusted based on the pressure-temperature load, which is monitored at a key location in the system.

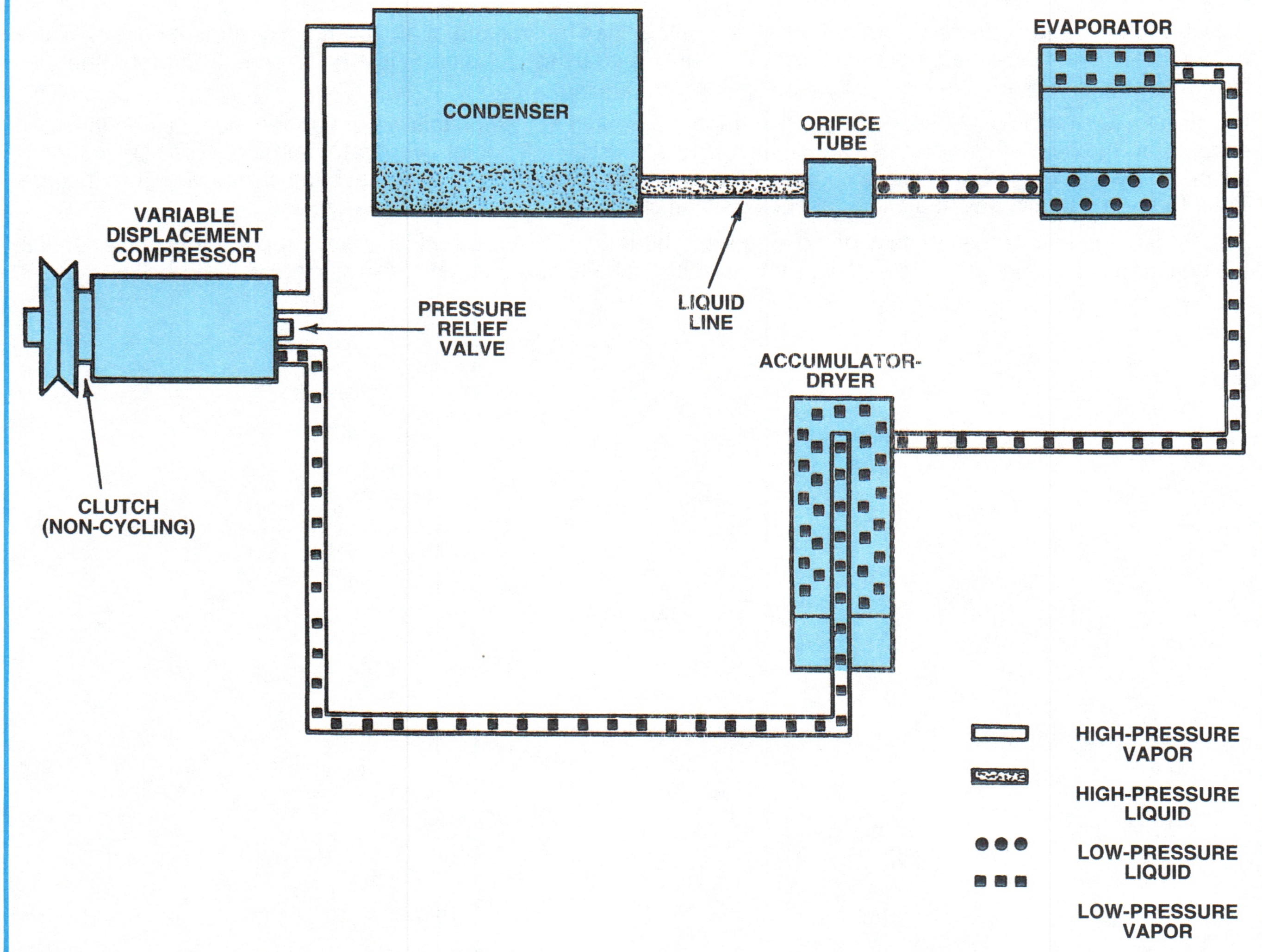

EVAPORATOR
CONDENSER
ORIFICE TUBE
VARIABLE DISPLACEMENT COMPRESSOR
PRESSURE RELIEF VALVE
LIQUID LINE
ACCUMULATOR-DRYER
CLUTCH (NON-CYCLING)
HIGH-PRESSURE VAPOR
HIGH-PRESSURE LIQUID
LOW-PRESSURE LIQUID
LOW-PRESSURE VAPOR

Figure 6-16, **High- and Low-Pressure Areas of the Refrigeration System**

Factors Affecting Heat Transfer Efficiency

The heat transfer efficiency of automotive A/C systems is greatly affected by "heat load" – the amount of heat that must be absorbed by the refrigerant. Factors affecting heat load are airflow at the condenser and evaporator, humidity, ambient temperatures, and sun load.

- **Coolant fan.** Engine coolant fans are an important part of the air conditioning system. In addition to causing engine overheating, a nonfunctional coolant fan hinders the heat transfer processes taking place at the condenser and radiator. Insufficient heat transfer at the condenser causes the compressor to work too hard at compressing the refrigerant vapor. This, in turn, causes compressor head pressure – or high-side pressure – to rise to unacceptable levels.
- **Condenser.** Any obstruction which reduces or blocks the air flow through the condenser will affect the efficiency of the condenser and the overall A/C refrigeration system performance. If air is diverted around the condenser (missing seals or damage to the air intake), the A/C refrigeration system performance will also be reduced.
- **Blower motor.** The blower motor affects evaporator heat transfer in the same way that the coolant fan affects condenser heat transfer.

  Blower motor speed controls airflow speed, which determines the volume of air flowing over the evaporator. This, in turn, determines the amount of heat that can be absorbed by the refrigerant in a given time. Therefore, the blower speed directly affects the heat exchange rate at the evaporator.
- **Humidity.** Humidity is a measure of the water vapor present in air. When this water vapor condenses on the evaporator, the heat of vaporization of the water is absorbed by the cooler evaporator surface. This heat is then absorbed by the refrigerant in the evaporator. This reduces the amount of heat that can be removed from the air. Therefore, on a humid day, the air is not cooled as efficiently as it is on a dry day.
- **Sun Load.** Sun load is the intensity of the long-wave heat rays from the sun. Ambient temperatures, together with the type and color of interior and exterior materials, affect heat load and, thus, the efficiency of the A/C system.

Notes

Notes

7. Thermal Control Systems Operation

Overview

The thermal control system maintains the drive motor, Power Inverter Module (PIM), charge receptacle and battery pack within normal operating temperatures. The thermal control system also controls cabin temperature based on commands from the vehicle operator. The thermal control system uses three different sub-systems to achieve thermal management:

- Fuel Fired Heater (FFH) System
- Coolant System
- Refrigeration/Heat Pump (R/HP) System

These three sub-systems allow the thermal control system to perform the following modes of operation:

- Battery pack cooling (R/HP System)
- Battery pack heating (R/HP System)
- Cabin cooling (R/HP System)
- Cabin heating (R/HP System or Fuel Fired Heater System)
- Charge receptacle cooling (Coolant System)
- Drive motor and PIM cooling (Coolant System)

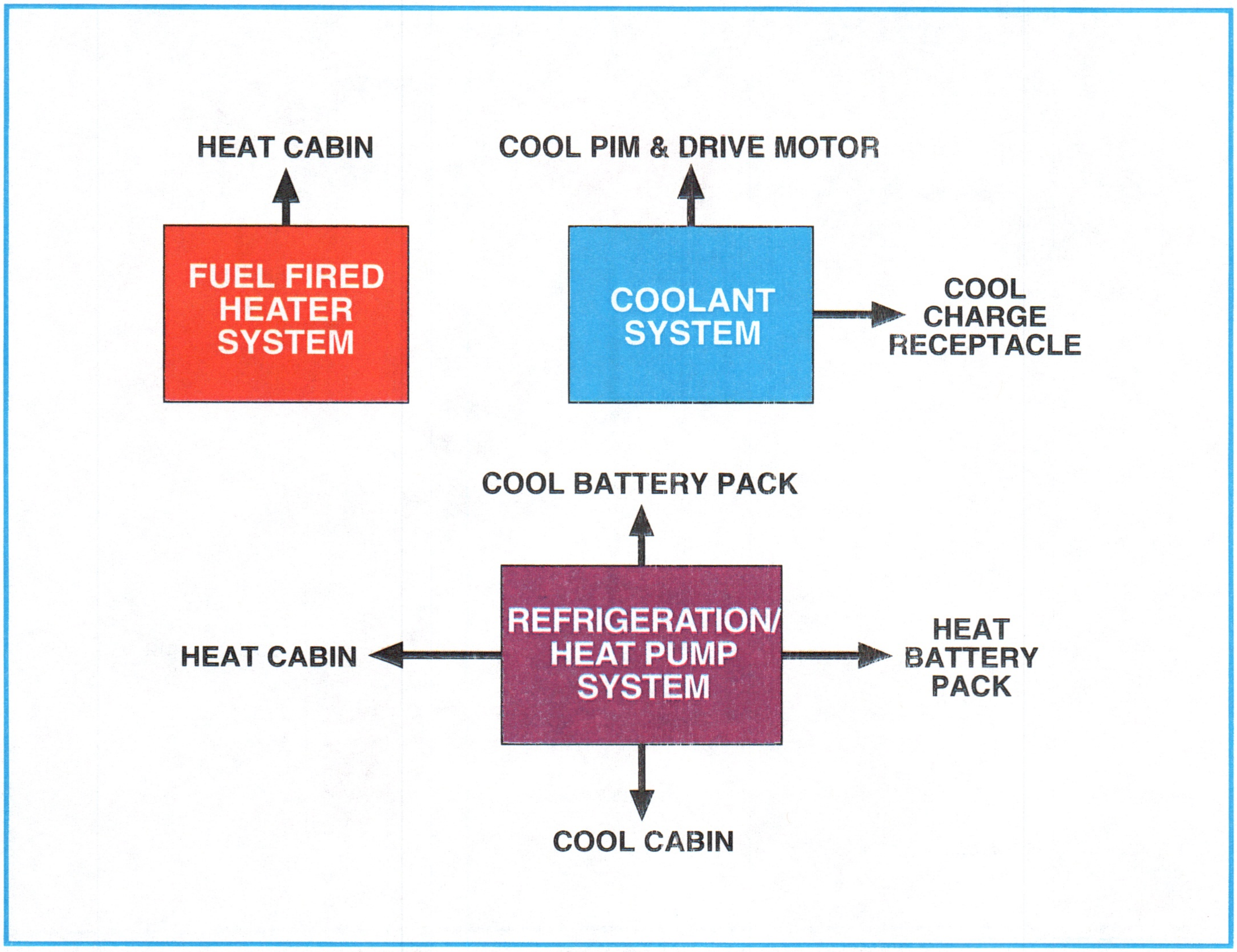
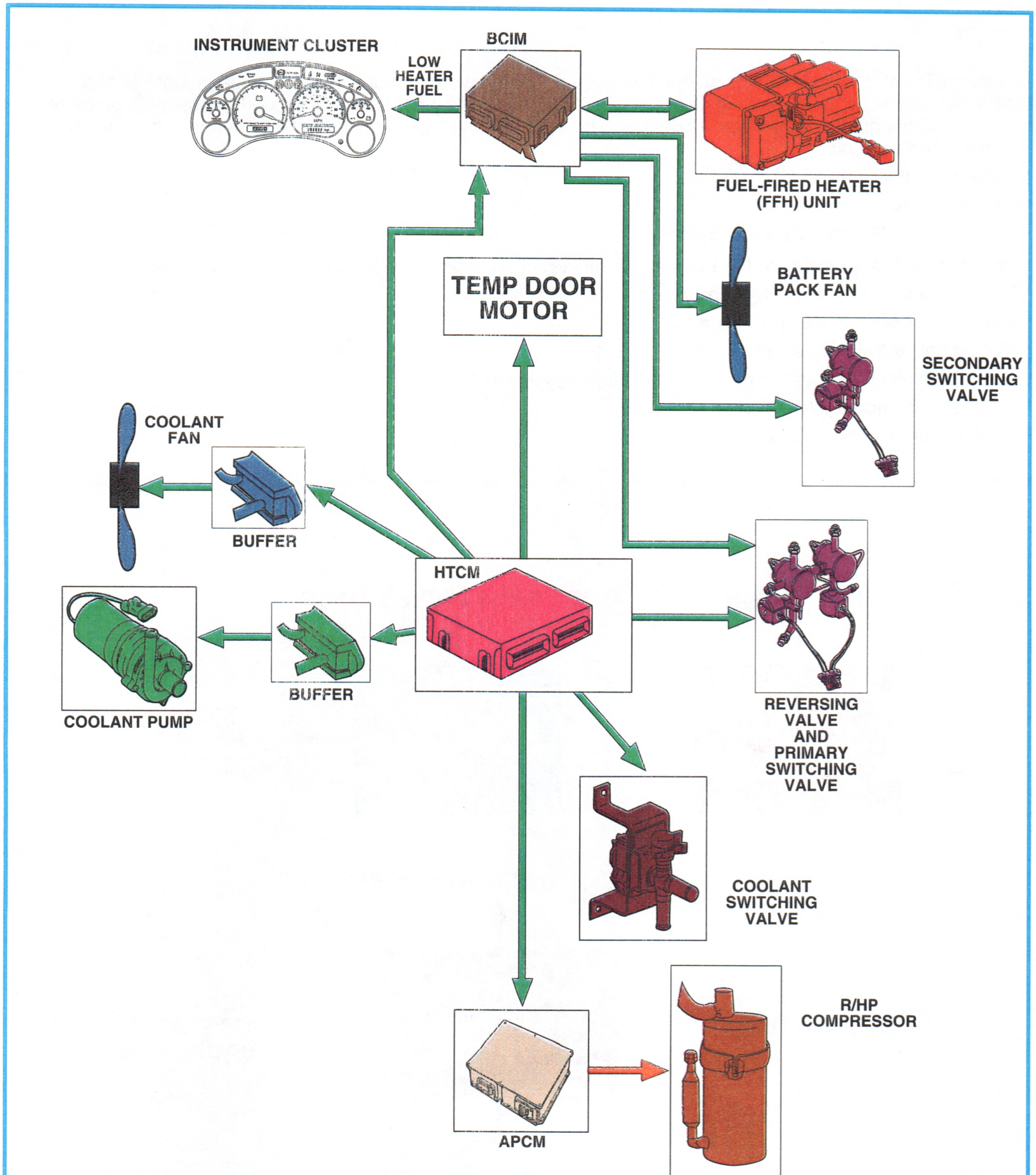

HEAT CABIN
FUEL FIRED HEATER SYSTEM
COOL PIM & DRIVE MOTOR
COOLANT SYSTEM
COOL CHARGE RECEPTACLE
COOL BATTERY PACK
HEAT CABIN
REFRIGERATION/ HEAT PUMP SYSTEM
HEAT BATTERY PACK
COOL CABIN

Figure 7-1, **Thermal Control System**


INSTRUMENT CLUSTER
BCIM
LOW HEATER FUEL
FUEL-FIRED HEATER (FFH) UNIT
TEMP DOOR MOTOR
BATTERY PACK FAN
SECONDARY SWITCHING VALVE
COOLANT FAN
BUFFER
HTCM
COOLANT PUMP
BUFFER
REVERSING VALVE AND PRIMARY SWITCHING VALVE
COOLANT SWITCHING VALVE
R/HP COMPRESSOR
APCM

ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

Figure 7-2, Heating and Thermal Control Module (HTCM) Outputs

Overview – Continued

The Heating and Thermal Control Module (HTCM) is the primary controller for the thermal control system. The HTCM receives inputs from the HVAC controller, Power Inverter Module (PIM), Battery Pack Control Module (BPCM) and Accessory Power Control Module (APCM). The PIM and BPCM provide input to the HTCM on the UART data line. The HTCM also receives inputs from the refrigerant pressure sensors, heat switch, and other sensors for drive-motor winding temperature, air temperature, and battery pack air flow (refer to Figure 7-3).

The HTCM controls the following outputs (refer to Figure 7-2):

- Temperature Door Motor (Air Distribution System)
- Battery Pack Fan
- Reversing and Primary Valves (R/HP System)
- Secondary Switching Valve (R/HP System)
- Coolant Switching Valve (Coolant System)
- Compressor (R/HP System)
- Fuel Fired Heater (FFH) Unit
- Coolant Fan and Pump
- BCIM Input to the Instrument Cluster

Some of the HTCM outputs are indirectly controlled by the HTCM. To control these outputs, the HTCM requests the BCIM to either energize the relay coil for that output or provide a ground path for the output.

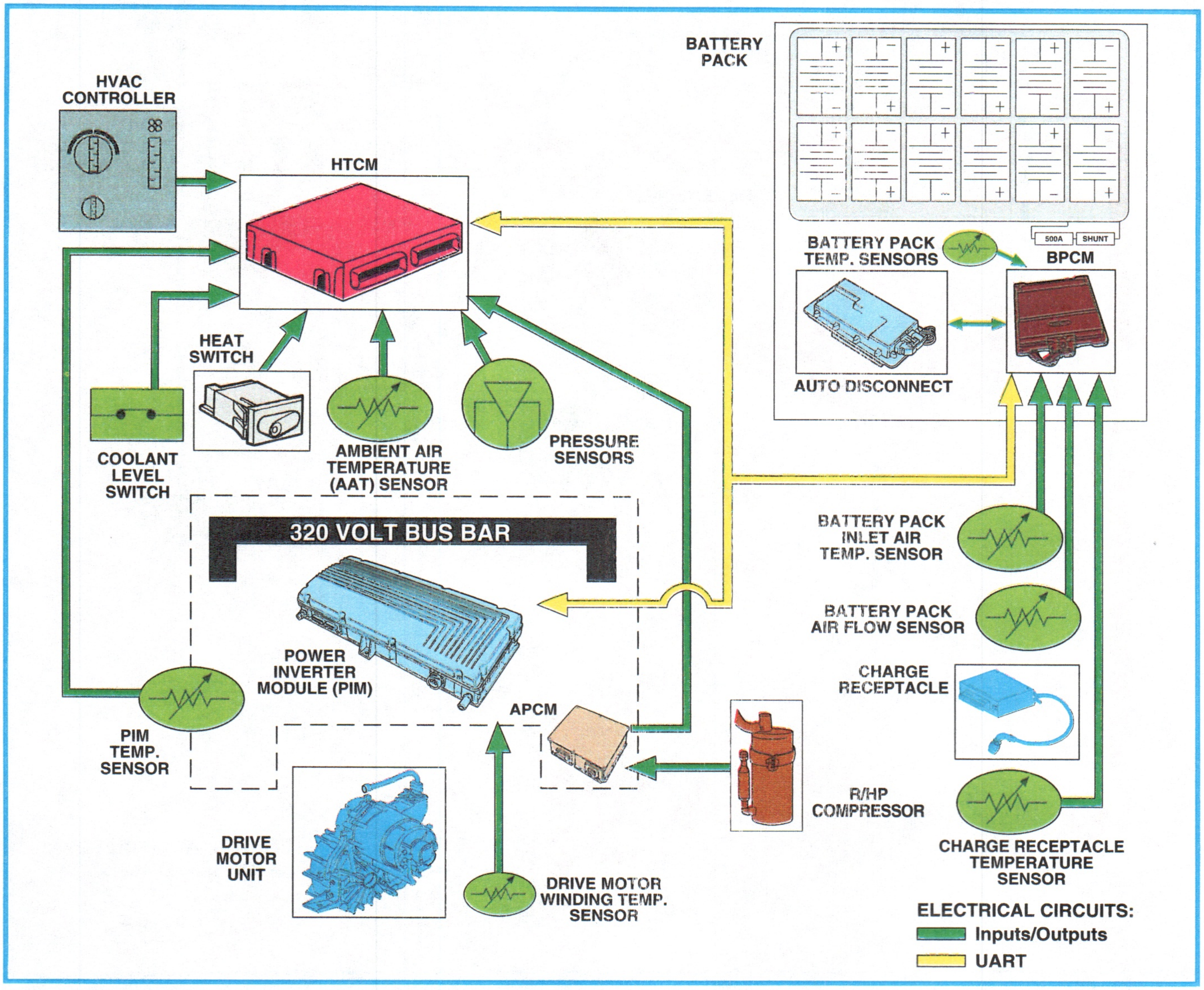

BATTERY PACK
HVAC CONTROLLER
HTCM
BATTERY PACK TEMP. SENSORS
500A
SHUNT
BPCM
AUTO DISCONNECT
HEAT SWITCH
AMBIENT AIR TEMPERATURE (AAT) SENSOR
PRESSURE SENSORS
COOLANT LEVEL SWITCH
320 VOLT BUS BAR
BATTERY PACK INLET AIR TEMP. SENSOR
BATTERY PACK AIR FLOW SENSOR
POWER INVERTER MODULE (PIM)
CHARGE RECEPTACLE
APCM
PIM TEMP. SENSOR
R/HP COMPRESSOR
DRIVE MOTOR UNIT
CHARGE RECEPTACLE TEMPERATURE SENSOR
DRIVE MOTOR WINDING TEMP. SENSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART

Figure 7-3, Heating and Thermal Control Module (HTCM) Inputs

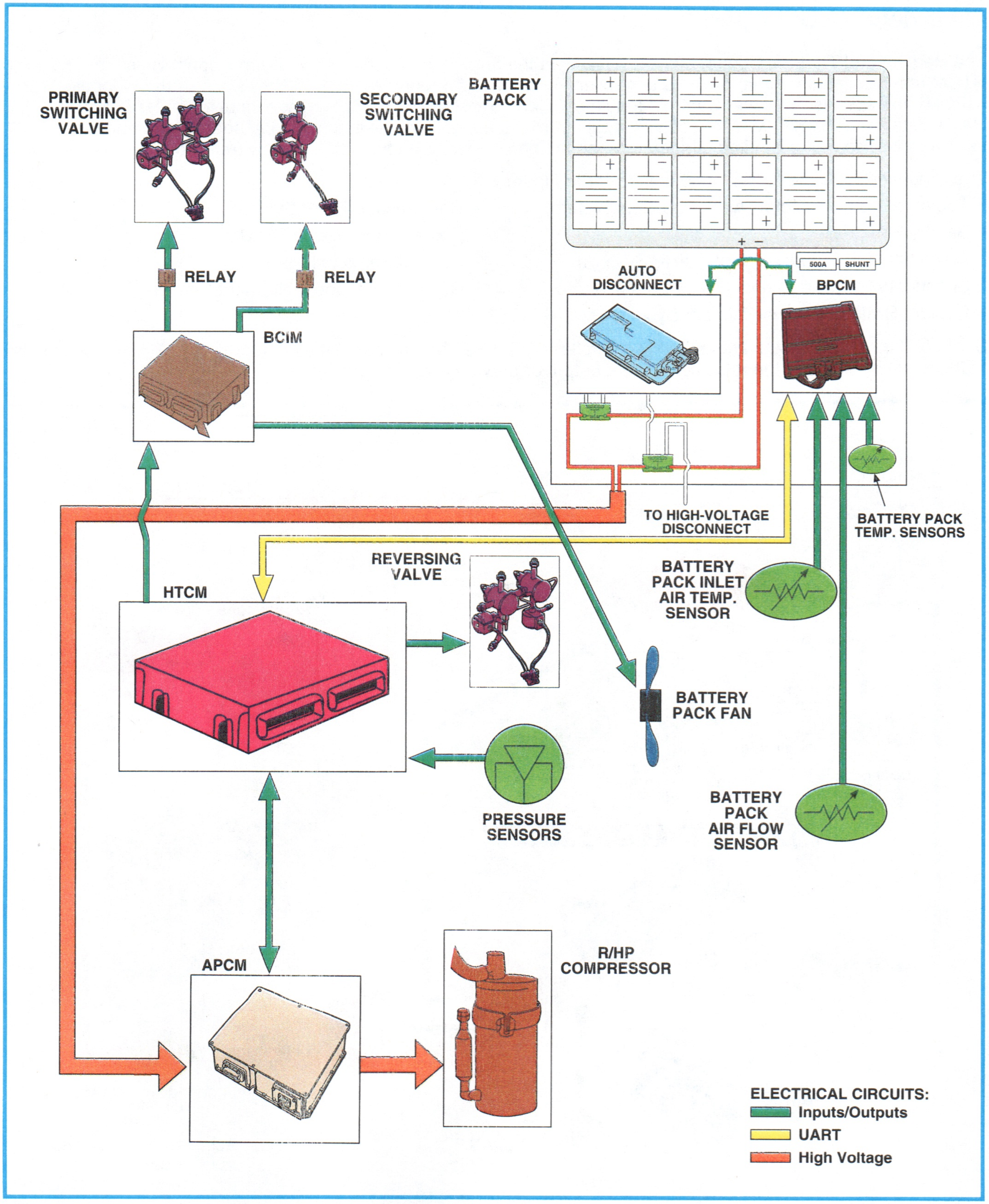

PRIMARY SWITCHING VALVE
SECONDARY SWITCHING VALVE
BATTERY PACK
+ −
500A
SHUNT
RELAY
RELAY
AUTO DISCONNECT
BPCM
BCIM
TO HIGH-VOLTAGE DISCONNECT
BATTERY PACK TEMP. SENSORS
REVERSING VALVE
HTCM
BATTERY PACK INLET AIR TEMP. SENSOR
BATTERY PACK FAN
PRESSURE SENSORS
BATTERY PACK AIR FLOW SENSOR
APCM
R/HP COMPRESSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟧 High Voltage

Figure 7-4, Battery Pack Thermal Management

Battery Pack Thermal Management

The Battery Pack Control Module (BPCM) monitors the six battery pack temperature sensors, the battery pack air flow sensor and battery pack inlet air temperature sensor to determine if thermal management is needed. If the BPCM determines there is a need for thermal management, it will request battery pack thermal management from the HTCM on the UART data line (refer to Figure 7-4).

The HTCM can provide the following modes of battery pack thermal management:

- Battery pack ventilation
- Battery pack heating
- Battery pack cooling

When the HTCM receives either an ignition "wake-up" or charging "wake-up," it will perform battery pack ventilation. During battery pack ventilation, the HTCM will command the battery pack fan to cycle ON for 1.5 minutes and then OFF for 8.5 minutes. The HTCM controls the battery pack fan by commanding the BCIM to provide a ground path for the fan circuit. The HTCM will continue this ON/OFF cycle until it no longer receives the "wake-up" voltage. The cycling of the battery pack fan is used to exhaust battery gases in the battery pack. The battery pack fan will not cycle OFF when the R/HP compressor is ON.

During battery pack ventilation, the BPCM monitors the battery pack air flow sensor. The battery pack air flow sensor is a thermistor mounted in the air stream entering the battery pack. Based on the resistance of the battery pack air flow sensor, the BPCM can determine the amount of air flow through the battery pack. If the air flow falls below a parameter in the BPCM software, the BPCM can disable charging and propulsion. Decreased air flow can be the result of a malfunctioning battery pack fan, obstructions in the battery pack or damage to the battery pack.

Battery pack heating is used when the battery pack temperature falls below normal operating temperature. The BPCM determines battery pack temperature from an average of the six battery pack temperature sensor signals. The battery pack sensors are thermistors located throughout the battery pack. These sensors provide the BPCM with an overall battery pack temperature and can help the BPCM determine the temperature of certain groups of battery modules.

If the BPCM determines the need for battery pack heating, it will request (on the UART data line) the HTCM to provide battery pack heating. If there are no malfunctions that prevent this action, the HTCM will control the position of the reversing, primary and secondary valves and command the APCM to turn on the compressor. The APCM will control the compressor based on the signal from the HTCM. The APCM will also provide compressor feedback to the HTCM. During compressor operation, the HTCM monitors the two refrigeration pressure sensors (refer to R/HP System Operation in this section for more information). Battery pack heating can only occur during charging.

Battery pack cooling is used to cool the battery pack when the pack temperature exceeds normal operating temperatures. During charging the BPCM will command cooling if any one of the battery pack temperature sensors indicates excessive heat. During propulsion, the BPCM takes an average of all the battery pack temperature sensors and will command cooling if the average indicates a temperature exceeding the normal operating temperatures. The BPCM can also command cooling in Park (not charging). The temperature for battery pack cooling in Park is based on battery pack temperature and the average state-of-charge of the battery pack.

If the BPCM determines the need for battery pack cooling, it will request the HTCM to provide battery pack cooling. If there are no malfunctions that prevent this action, the HTCM will control the position of the reversing and secondary valves and command the APCM to turn on the compressor.

Cabin Thermal Management

The cabin temperature is controlled by the HTCM based on inputs from the HVAC controller, Fuel Fired Heater (FFH) switch and ambient air temperature sensor. The vehicle operator controls cabin thermal management by selecting the position of the mode selector switch, temperature switch and FFH switch. The HTCM and HVAC controller can provide the following modes of cabin thermal management control:

- Cabin Cooling (MAX A/C, NORM A/C and BI-LEV A/C)
- Cabin Heating (HEAT and BLEND)
- Vent
- Defrost

The HTCM can control the temperature inside the cabin by using either the Fuel Fired Heater (FFH) system and/or the R/HP System (refer to Figure 7-5). The FFH system is only available for use when the ambient temperature is below 40°F and the vehicle operator turns the Heat switch to the ON position. Refer to Fuel Fired Heater System Operation in this section for more information.

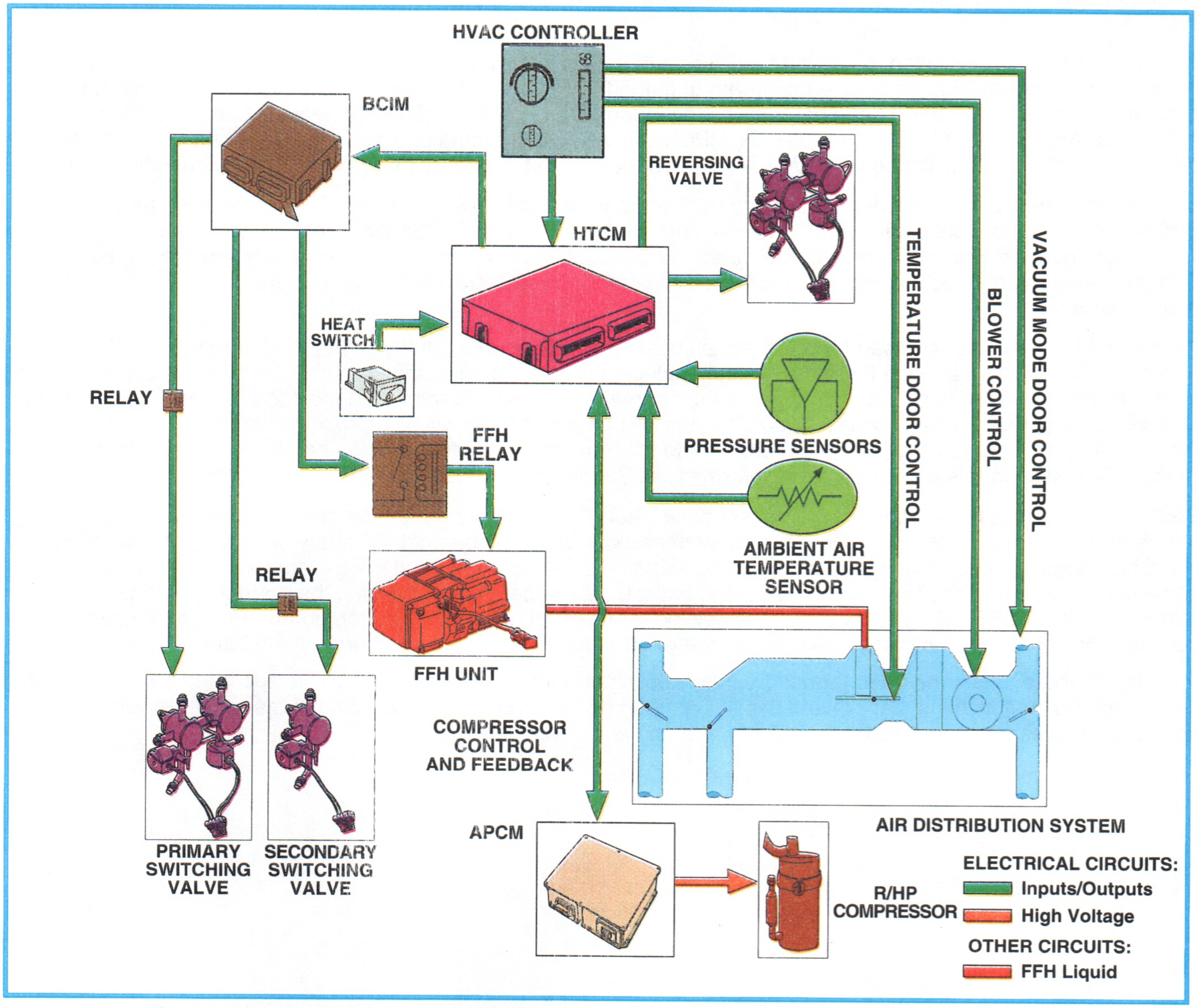

HVAC CONTROLLER
BCIM
REVERSING VALVE
HTCM
HEAT SWITCH
RELAY
FFH RELAY
PRESSURE SENSORS
TEMPERATURE DOOR CONTROL
BLOWER CONTROL
VACUUM MODE DOOR CONTROL
AMBIENT AIR TEMPERATURE SENSOR
RELAY
FFH UNIT
COMPRESSOR CONTROL AND FEEDBACK
PRIMARY SWITCHING VALVE
SECONDARY SWITCHING VALVE
APCM
AIR DISTRIBUTION SYSTEM
R/HP COMPRESSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage
OTHER CIRCUITS:
🟥 FFH Liquid

Figure 7-5, Cabin Temperature Control

The R/HP System can provide both heating and cooling for the cabin. Below 40°F, the ability of the R/HP System to provide heat to the cabin is limited. Refer to R/HP System Operation in this section for more information.

The air distribution system is similar to other S10 trucks. The air distribution system has a blower, heater core, recirculation door, A/C (dash) door and a floor/defrost door (refer to Figure 7-6). The evaporator core is referred to as the Center EXchanger (CEX) because it can provide both warming and cooling.

The electric truck system uses a motor with a feedback circuit to control the temperature door. This motor is controlled by the HTCM. The HVAC control head directly controls the A/C (dash) door, recirculation door and a floor/defrost door by using vacuum. The blower is controlled by the position of the fan switch. Depending on the switch position, the current to the blower will be varied by use of a resistor module.

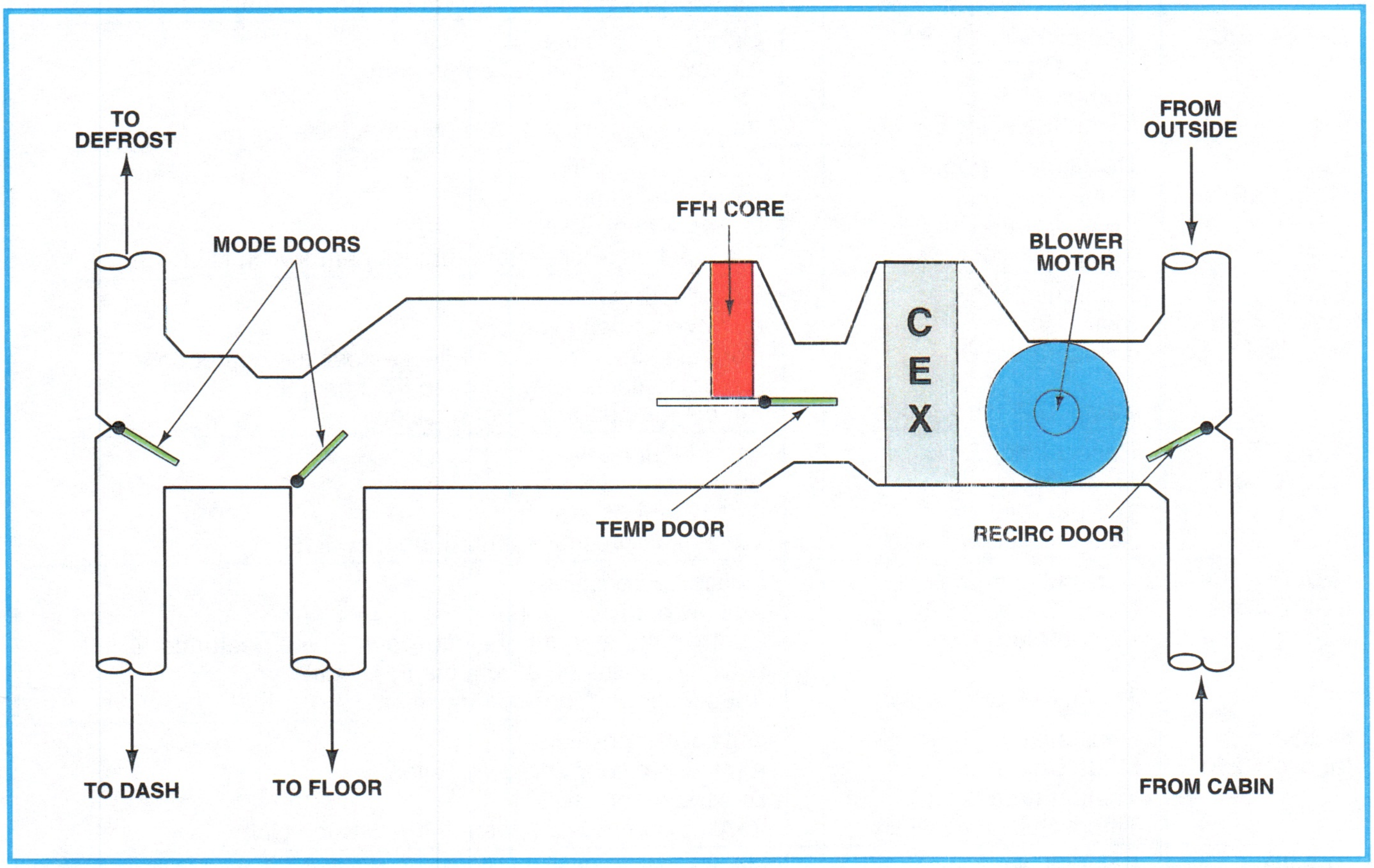


Figure 7-6, Air Distribution System

MODE SWITCH POSITION	COMPONENT	OPERATION OR POSITION
MAX A/C	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Recirculation position Air flow out dash vents Full cold position Varies compressor speed (which affects temperature)
NORM A/C	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out dash vents Full cold position Varies compressor speed (which affects temperature)
BI-LEV A/C	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out dash and floor vents Full cold position Varies compressor speed (which affects temperature)
VENT (above 40°F)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out dash vents Dependent on switch No affect on temperature (unless heat switch ON)
VENT (below 40°F with FFH on)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out dash vents Controls the amount of air flow across the heater core (which contains heat from the FFH unit) Affects temperature door position
HEATER (above 40°F)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out floor vents Dependent on switch Varies compressor speed (if heat switch ON)
HEATER (below 40°F with FFH on)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out floor vents Controls the amount of air flow across the heater core (which contains heat from the FFH unit) Affects temperature door position
BLEND (above 40°F)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out floor and defrost vents Dependent on switch Varies compressor speed (if heat switch ON)
BLEND (below 40°F with FFH on)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out floor and defrost vents Controls the amount of air flow across the heater core (which contains heat from the FFH unit) Affects temperature door position
DEFROST (above 40°F)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside Air position Air flow out defrost vents Dependent on switch Varies compressor speed (if heat switch ON)
DEFROST (below 40°F with FFH on)	Recirculation Door Mode Doors Temperature Door Temp. Selector Switch	Outside air position Air flow out defrost vents Controls the amount of air flow across the heater core (which contains heat from the FFH unit) Affects temperature door position

Figure 7-7, **Air Distribution System Operation**

Cabin Thermal Management – Continued

The HVAC control head provides input to the HTCM based on the position of the temperature selector switch. This input provides the HTCM with desired cabin temperature. The HTCM will control various outputs to provide the desired cabin thermal management. These outputs include:

- R/HP System Compressor
- Fuel Fired Heater (only with the switch in the ON position)
- Reversing and Secondary Valves (R/HP System)
- Temperature Door Motor

If the BPCM is requesting thermal management, the HTCM will not provide heating or cooling through the CEX.

The cabin temperature control system is in many ways unlike conventional HVAC systems. Since the heater core will only provide heat below 40°F (with the Heat switch ON), the temperature door is often ineffective (refer to Figure 7-8).

When the FFH system is operating, the temperature door will be effective in varying the temperature by controlling the amount of air that passes through the heater core. Figure 7-7 shows the cabin temperature control system operation for the various mode switch positions.

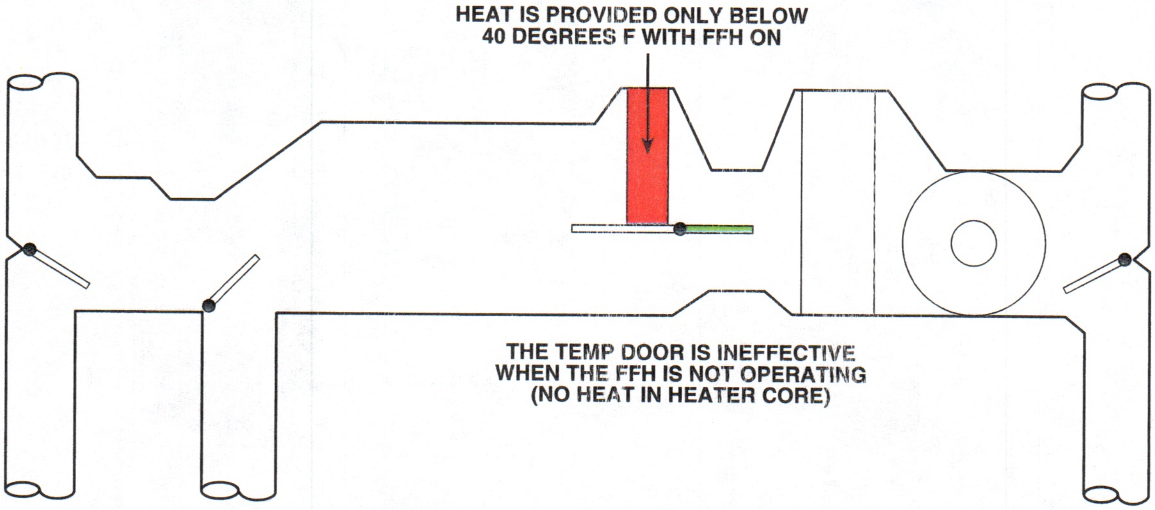

HEAT IS PROVIDED ONLY BELOW
40 DEGREES F WITH FFH ON
THE TEMP DOOR IS INEFFECTIVE
WHEN THE FFH IS NOT OPERATING
(NO HEAT IN HEATER CORE)

Figure 7-8, **Cabin Temperature Control**

Refrigeration/Heat Pump (R/HP) System Operation

The Refrigeration/Heat Pump (R/HP) system can provide heating or cooling to the battery pack or the cabin. The R/HP system is controlled by the HTCM. The following are the R/HP system components (refer to Figure 7-9):

- Compressor
- Reversing Valve/Primary Switching Valve
- Secondary Switching Valve
- Accumulator/Dryer
- Front EXchanger (FEX)
- Center EXchanger (CEX)
- Rear EXchanger (REX)
- Orifice Tube
- High-Side Pressure Sensor
- Low-Side Pressure Sensor
- R 134a Refrigerant

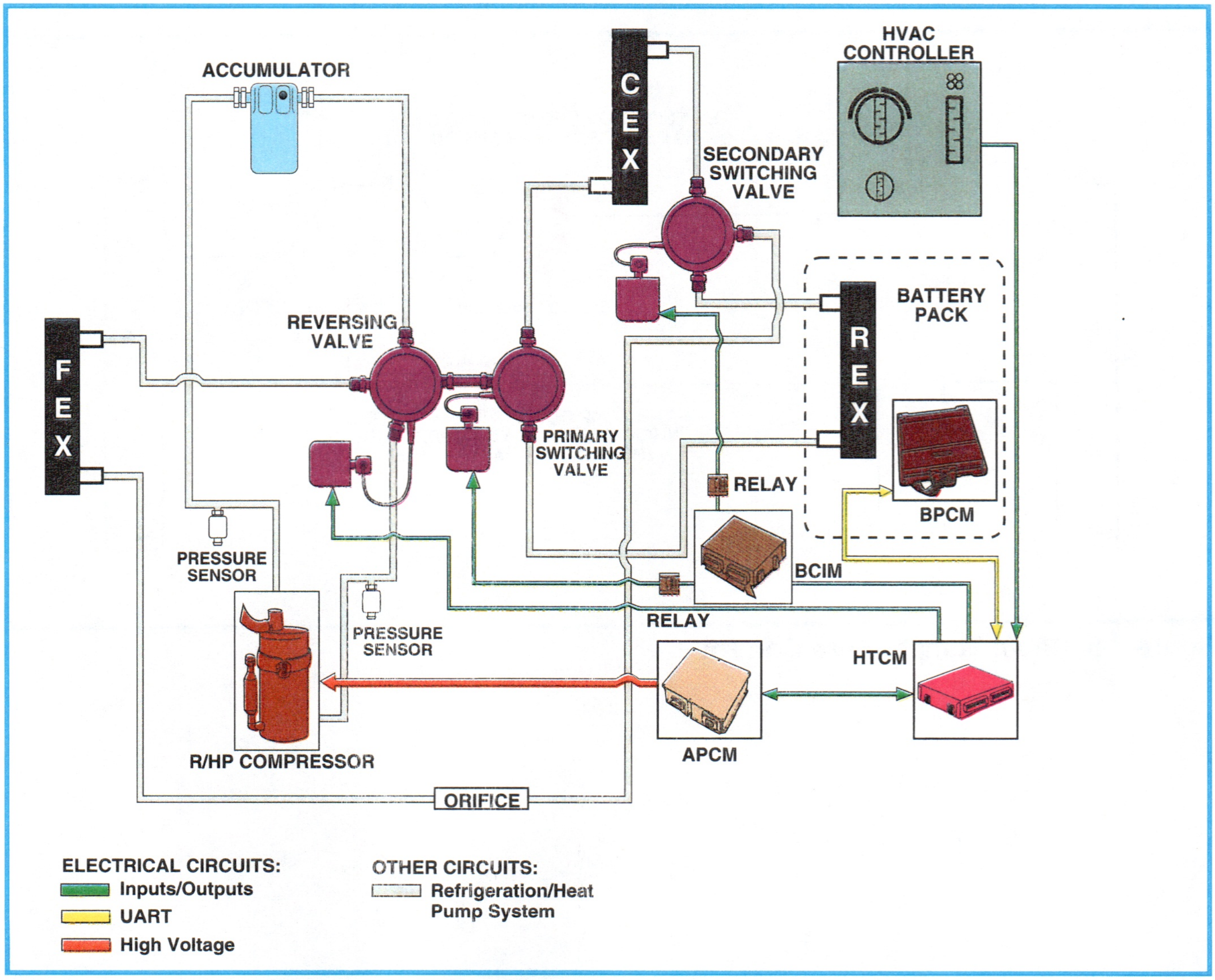

ACCUMULATOR
CEX
HVAC CONTROLLER
SECONDARY SWITCHING VALVE
BATTERY PACK
REX
REVERSING VALVE
FEX
PRIMARY SWITCHING VALVE
RELAY
BPCM
PRESSURE SENSOR
BCIM
RELAY
PRESSURE SENSOR
HTCM
R/HP COMPRESSOR
APCM
ORIFICE
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟥 High Voltage
OTHER CIRCUITS:
☐ Refrigeration/Heat Pump System

Figure 7-9, Refrigeration/Heat Pump System Components

The compressor used in the system is a variable speed 3-phase AC compressor. The APCM is used by the HTCM to control the high voltage circuit (from the 320-volt battery pack) to the compressor. The HTCM provides a speed signal to the APCM and the APCM controls the speed of the compressor. The APCM provides the HTCM with feedback for each phase of the compressor. By controlling the speed of the compressor, the HTCM can regulate the amount of heat exchange that occurs at the exchangers.

The HTCM uses the pressure sensors to monitor the system. The HTCM will either reduce compressor speed or stop the compressor if the sensors indicate pressures outside of the HTCM parameters. The HTCM will inhibit compressor operation if the sensor(s) indicate excessively high or low pressure, caused by overcharging, undercharging or low ambient temperature. The HTCM will also control the compressor speed to prevent liquid refrigerant from entering the compressor. The accumulator/dryer also helps to prevent liquid refrigerant from entering the compressor.

The reversing, primary and secondary valves are used to control the flow of refrigerant (refer to Figure 7-10). Each valve is controlled by a solenoid. The primary and secondary switching valves have two positions and allow the refrigerant to flow to either the exchanger in the cabin (CEX) or the exchanger in the battery pack (REX). The reversing valve controls the direction of refrigerant flow. In one position, the valve allows the output of the compressor to enter the FEX. In the other position, the valve allows the output of the compressor to enter either the CEX or REX (depending on the position of the switching valves).

The HTCM determines the positions of the reversing valves based on requests for thermal management from the BPCM and the HVAC control head. If both controllers request thermal management, the HTCM will always perform battery pack thermal management before cabin thermal management.

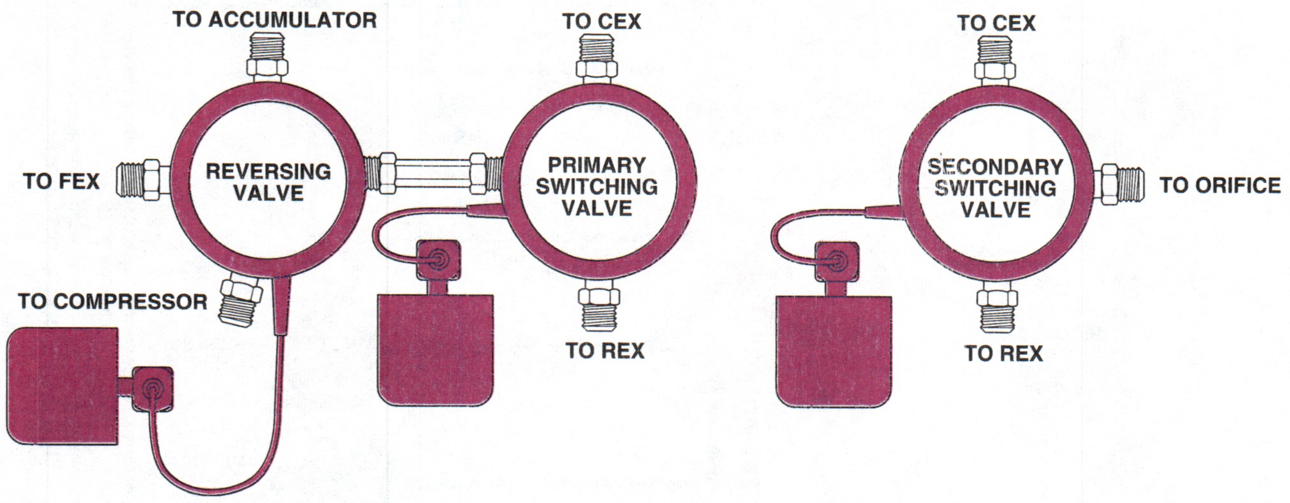


Figure 7-10, **Refrigerant Reversing Valve and Primary/Secondary Switching Valves**

Cabin Cooling

The cabin temperature is controlled by the HTCM (see Figure 7-11). The HTCM receives input from the HVAC control head on desired temperature. The R/HP system provides cold liquid refrigerant to the Cabin EXchanger (CEX) when the mode switch is in the following positions:

- MAX A/C
- NORM A/C
- BI-LEV A/C
- DEFROST

The temperature selector switch is used to control the compressor speed under certain operating conditions. Refer to Cabin Thermal Management in this section for more information.

When the HTCM commands the compressor on, it also commands the coolant fan on. The fan will operate at a slightly higher speed when the compressor is on. The coolant fan helps to provide air flow through the Front EXchanger (FEX).

During cabin cooling, the refrigerant flows through the R/HP system in the following manner (see Figure 7-12):

- The compressor pushes high pressure vapor to the FEX.
- The FEX condenses the high pressure vapor into a high pressure liquid by allowing heat from the vapor to transfer to the outside air.
- The high pressure liquid is pushed from the FEX to the orifice.

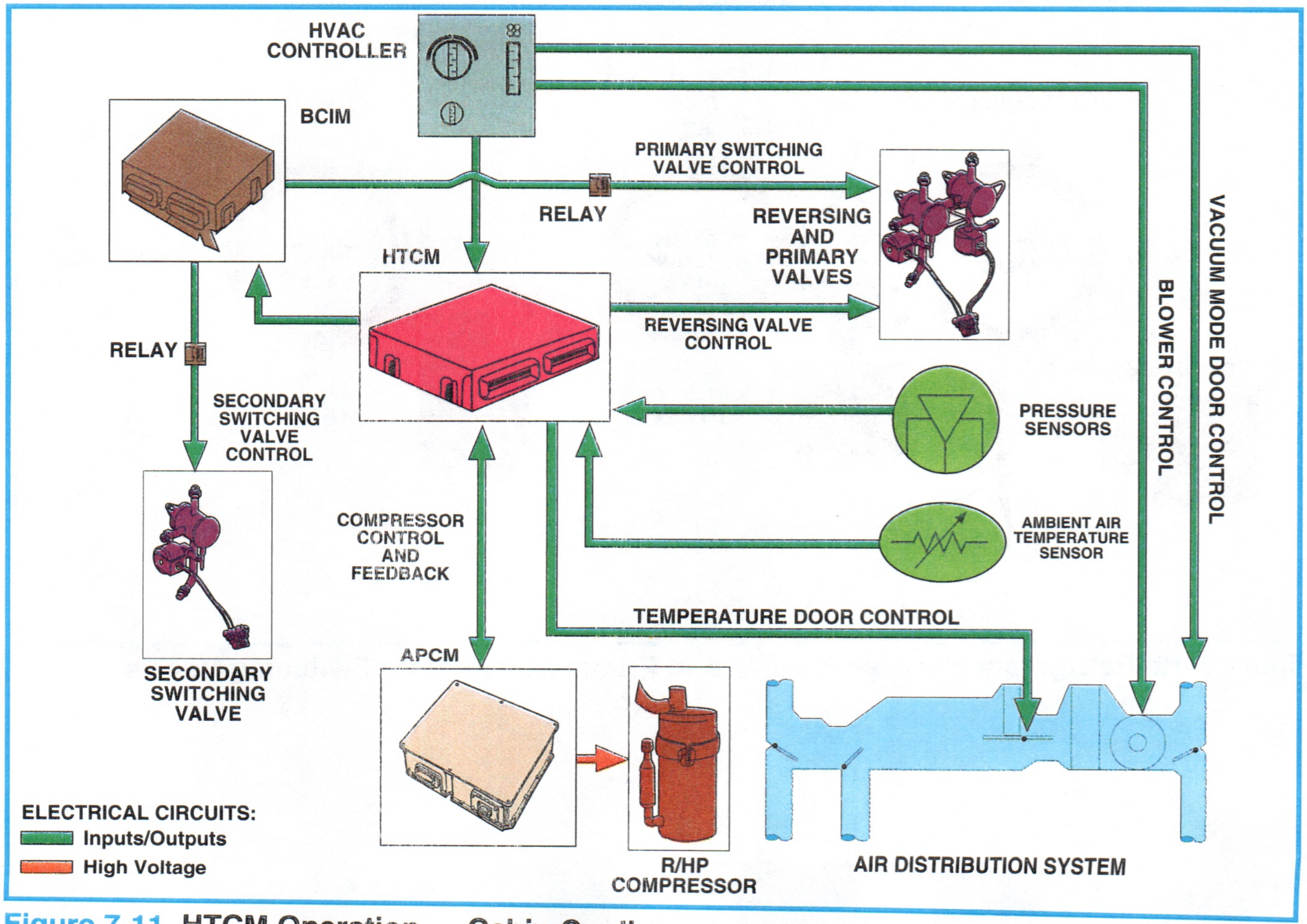

HVAC CONTROLLER
BCIM
PRIMARY SWITCHING VALVE CONTROL
RELAY
REVERSING AND PRIMARY VALVES
HTCM
REVERSING VALVE CONTROL
VACUUM MODE DOOR CONTROL
BLOWER CONTROL
RELAY
SECONDARY SWITCHING VALVE CONTROL
PRESSURE SENSORS
COMPRESSOR CONTROL AND FEEDBACK
AMBIENT AIR TEMPERATURE SENSOR
TEMPERATURE DOOR CONTROL
APCM
SECONDARY SWITCHING VALVE
R/HP COMPRESSOR
AIR DISTRIBUTION SYSTEM
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

Figure 7-11, HTCM Operation — Cabin Cooling

- The orifice provides a restriction for the compressor to push against, and it separates the high pressure side of the refrigeration system from the low pressure side. The lower pressure on the low pressure side of the orifice causes the temperature and pressure of the liquid refrigerant to decrease (due to the pressure-temperature relationship).
- The refrigerant moves from the orifice to the CEX.
- The CEX allows the heat from the outside air to transfer to the low pressure liquid and causes it to change state into a low pressure gas. The blower moves the cooled outside air into the cabin.
- The low pressure gas moves from the CEX to the accumulator. The accumulator separates any residual liquid from the gas before it enters the compressor.
- The low pressure gas moves from the accumulator to the intake side of the compressor.

The cool cabin operation is similar to a conventional vehicle A/C system. The heat is removed from the air entering the air distribution system and it is released at the FEX.

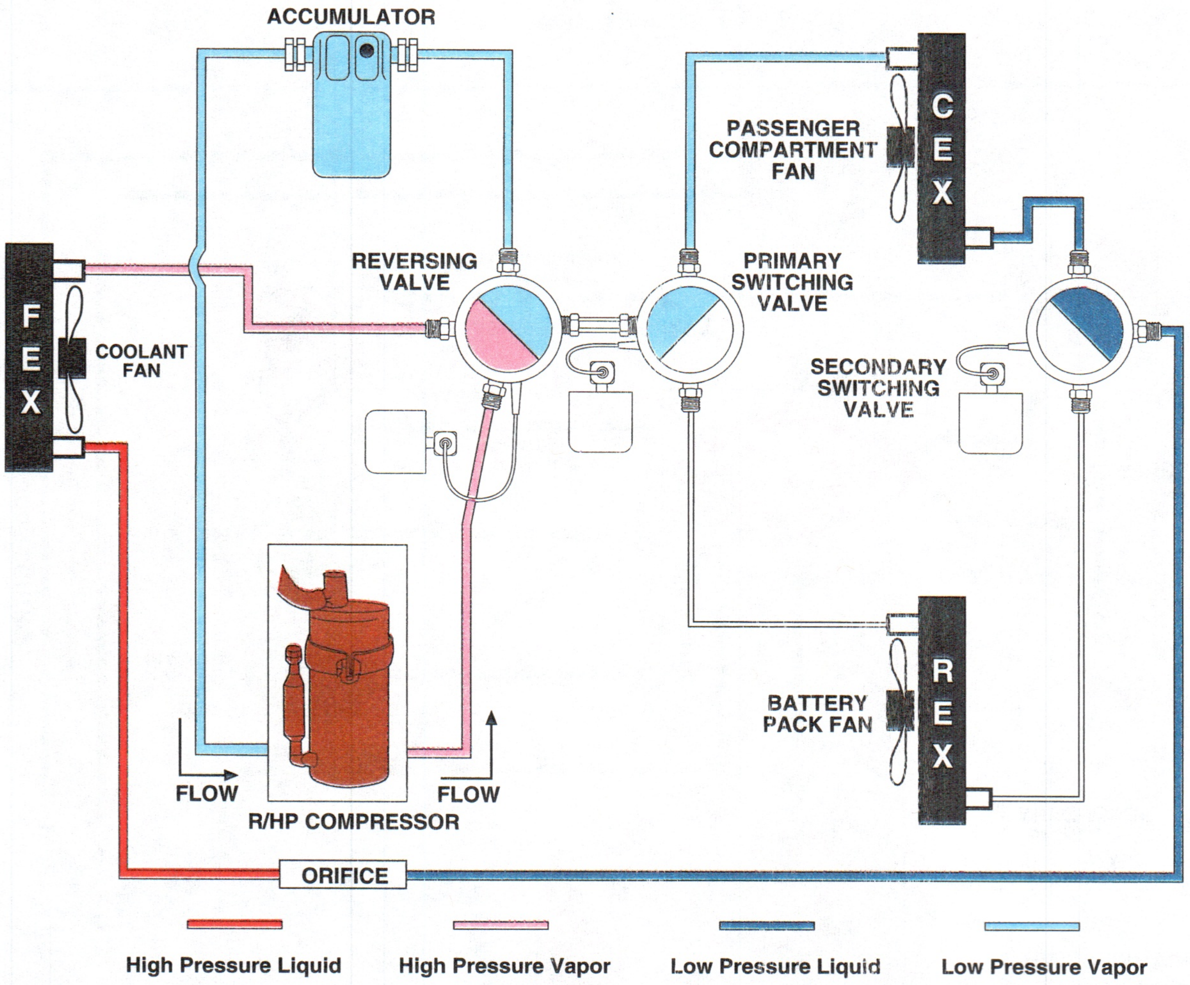

ACCUMULATOR
PASSENGER COMPARTMENT FAN
CEX
FEX
COOLANT FAN
REVERSING VALVE
PRIMARY SWITCHING VALVE
SECONDARY SWITCHING VALVE
BATTERY PACK FAN
REX
FLOW
FLOW
R/HP COMPRESSOR
ORIFICE
High Pressure Liquid
High Pressure Vapor
Low Pressure Liquid
Low Pressure Vapor

Figure 7-12, Refrigeration System — Cabin Cooling

Cabin Heating

The cabin temperature is controlled by the HTCM (see Figure 7-13). The HTCM receives input from the HVAC control head on desired temperature. The R/HP system scavenges heat from the outside air at the Front EXchanger (FEX) and transfers it to the Cabin EXchanger (CEX) when the heat switch is ON (above 40°F) and the mode switch is in the following positions:

- HEAT
- BLEND

The temperature selector switch is used to control the compressor speed under certain operating conditions. Refer to Cabin Thermal Management in this section for more information.

When the HTCM commands the compressor ON, it also commands the coolant fan ON. The fan will operate at a slightly higher speed when the compressor is on. The coolant fan helps to provide air flow through the Front EXchanger (FEX).

During cabin heating, the refrigerant flows through the R/HP system in the following manner (see Figure 7-14):

- The compressor pushes high pressure vapor to the CEX.
- The CEX condenses the high pressure vapor into a high pressure liquid by allowing heat from the vapor to transfer to the air entering the cabin.
- The high pressure liquid is pushed from the CEX to the orifice.

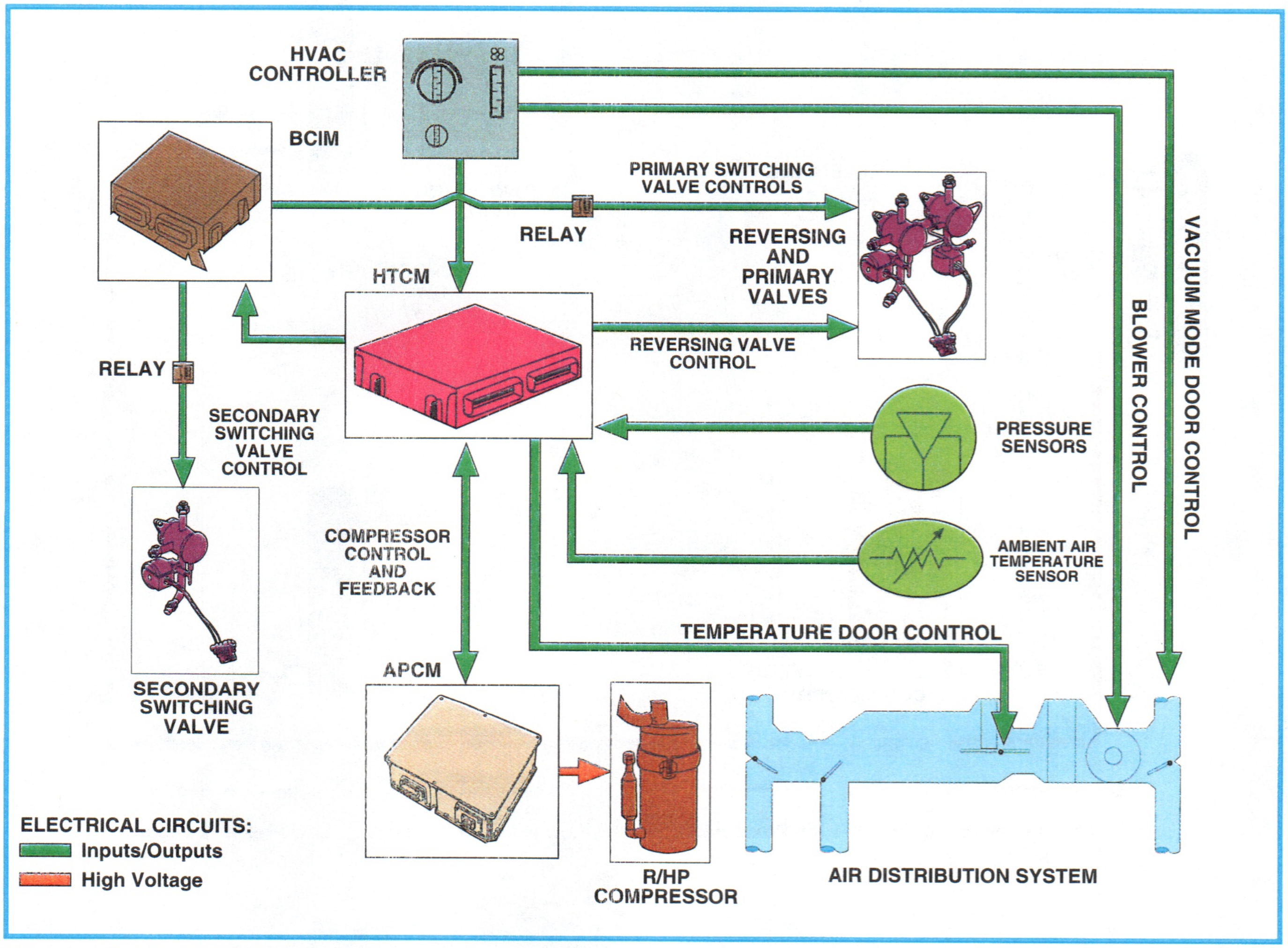

HVAC CONTROLLER
BCIM
PRIMARY SWITCHING VALVE CONTROLS
RELAY
REVERSING AND PRIMARY VALVES
HTCM
REVERSING VALVE CONTROL
RELAY
SECONDARY SWITCHING VALVE CONTROL
PRESSURE SENSORS
COMPRESSOR CONTROL AND FEEDBACK
AMBIENT AIR TEMPERATURE SENSOR
TEMPERATURE DOOR CONTROL
BLOWER CONTROL
VACUUM MODE DOOR CONTROL
SECONDARY SWITCHING VALVE
APCM
R/HP COMPRESSOR
AIR DISTRIBUTION SYSTEM
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

Figure 7-13, **HTCM Operation — Cabin Heating**

- The orifice provides a restriction for the compressor to push against, and it separates the high pressure side of the refrigeration system from the low pressure side. The lower pressure on the low pressure side of the orifice causes the temperature and pressure of the liquid refrigerant to decrease (due to the pressure-temperature relationship).
- The refrigerant moves from the orifice to the FEX.
- The FEX allows the heat from the outside air to transfer to the low pressure liquid and causes it to change state into a low pressure gas. The coolant fan pulls air through the FEX.
- The low pressure gas moves from the FEX to the accumulator. The accumulator separates any residual liquid from the gas before it enters the compressor.
- The low pressure gas moves from the accumulator to the intake side of the compressor.

The heat cabin operation is similar to a home heat pump system. The heat is removed from the outside air passing through the FEX and it is released to the air entering the cabin.

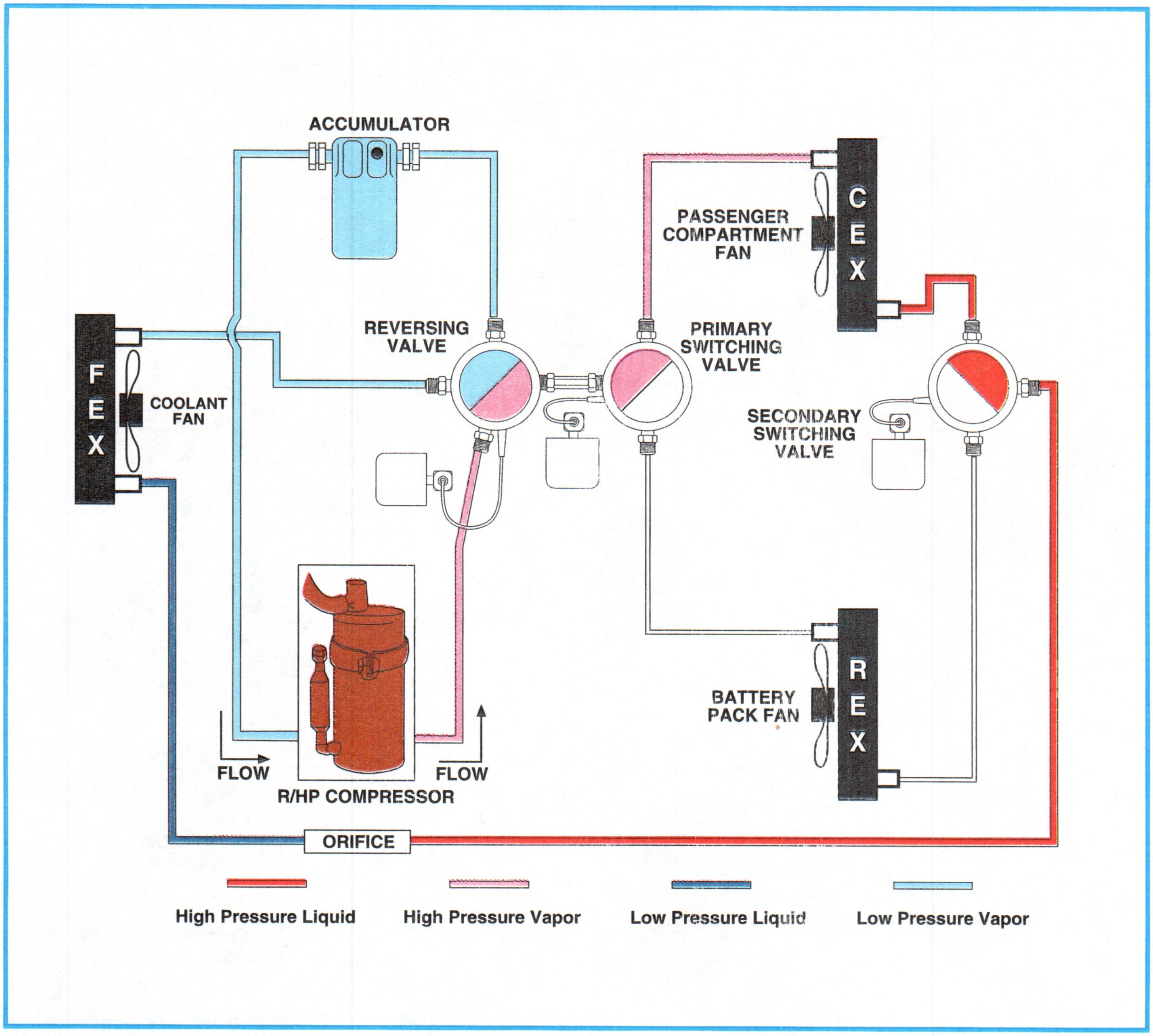

ACCUMULATOR
PASSENGER COMPARTMENT FAN
C E X
REVERSING VALVE
PRIMARY SWITCHING VALVE
F E X
COOLANT FAN
SECONDARY SWITCHING VALVE
BATTERY PACK FAN
R E X
FLOW
FLOW
R/HP COMPRESSOR
ORIFICE
High Pressure Liquid
High Pressure Vapor
Low Pressure Liquid
Low Pressure Vapor

Figure 7-14, Refrigeration System — Cabin Heating

Battery Pack Cooling

The battery pack thermal management is controlled by the HTCM (see Figure 7-15). The HTCM receives input from the BPCM to cool the battery pack when the temperature exceeds a BPCM parameter. The R/HP system provides cold liquid refrigerant to the Rear EXchanger (REX)

When the HTCM commands the compressor ON, it also commands ON both the coolant fan and battery pack fan. The coolant fan will operate at a slightly higher speed when the compressor is on. The fans help to provide air flow through the exchangers.

During battery pack cooling, the refrigerant flows through the R/HP system in the following manner (see Figure 7-16):

- The compressor pushes high pressure vapor to the FEX.
- The FEX condenses the high pressure vapor into a high pressure liquid by allowing heat from the vapor to transfer to the outside air.
- The high pressure liquid is pushed from the FEX to the orifice.

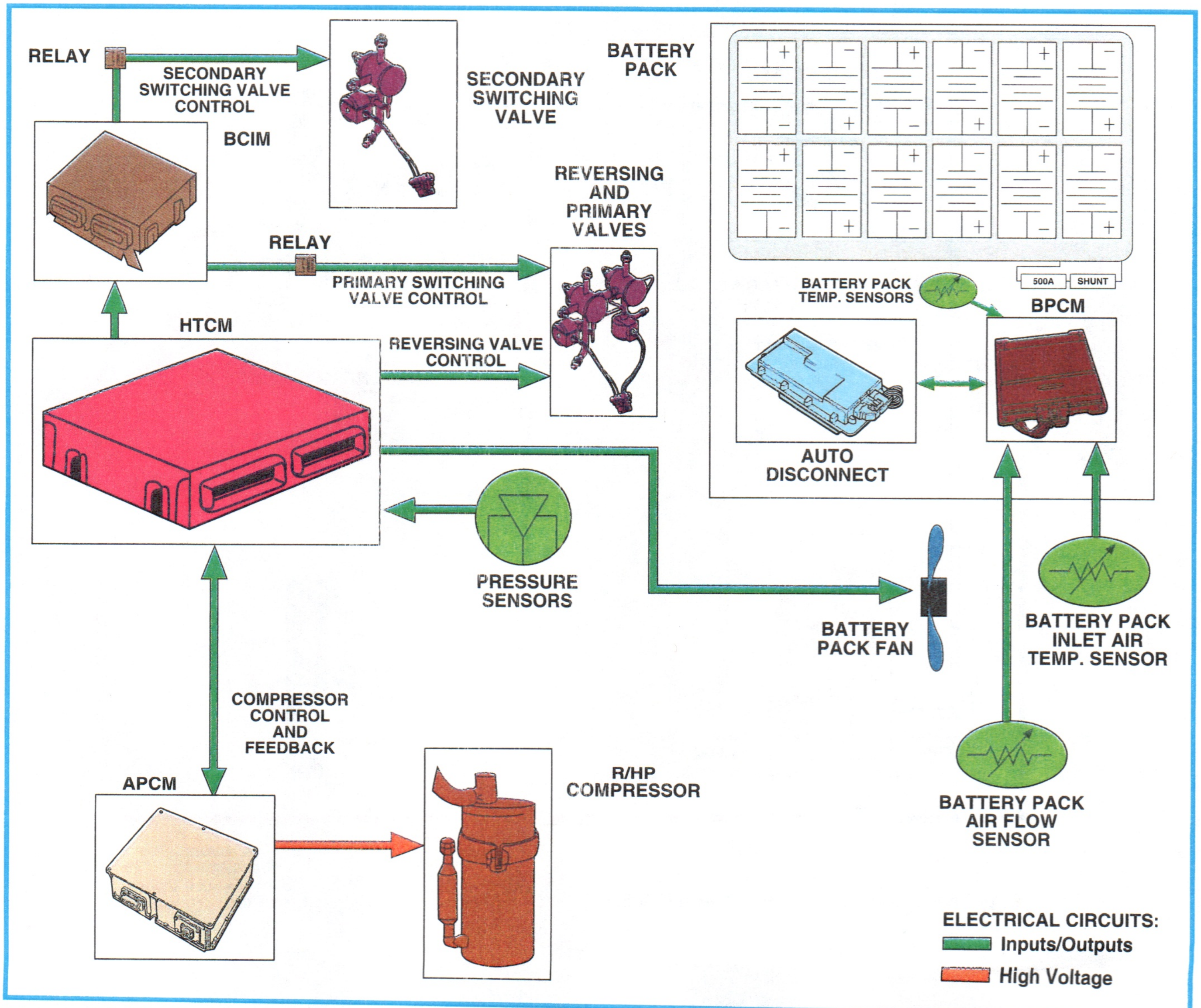

RELAY
SECONDARY SWITCHING VALVE CONTROL
SECONDARY SWITCHING VALVE
BATTERY PACK
BCIM
REVERSING AND PRIMARY VALVES
RELAY
PRIMARY SWITCHING VALVE CONTROL
BATTERY PACK TEMP. SENSORS
500A
SHUNT
BPCM
HTCM
REVERSING VALVE CONTROL
AUTO DISCONNECT
PRESSURE SENSORS
BATTERY PACK FAN
BATTERY PACK INLET AIR TEMP. SENSOR
COMPRESSOR CONTROL AND FEEDBACK
APCM
R/HP COMPRESSOR
BATTERY PACK AIR FLOW SENSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

Figure 7-15, **HTCM Operation — Battery Pack Cooling**

- The orifice provides a restriction for the compressor to push against, and it separates the high pressure side of the refrigeration system from the low pressure side. The lower pressure on the low pressure side of the orifice causes the temperature and pressure of the liquid refrigerant to decrease (due to the pressure-temperature relationship).
- The refrigerant moves from the orifice to the REX.
- The REX allows the heat from the outside air to transfer to the low pressure liquid and causes it to change state into a low pressure gas. The battery pack fan moves the cooled outside air into the battery pack.
- The low pressure gas moves from the REX to the accumulator. The accumulator separates any residual liquid from the gas before it enters the compressor.
- The low pressure gas moves from the accumulator to the intake side of the compressor.

The cool battery pack operation is similar to a conventional vehicle A/C system. The heat is removed from the air entering the battery pack and it is released at the FEX.

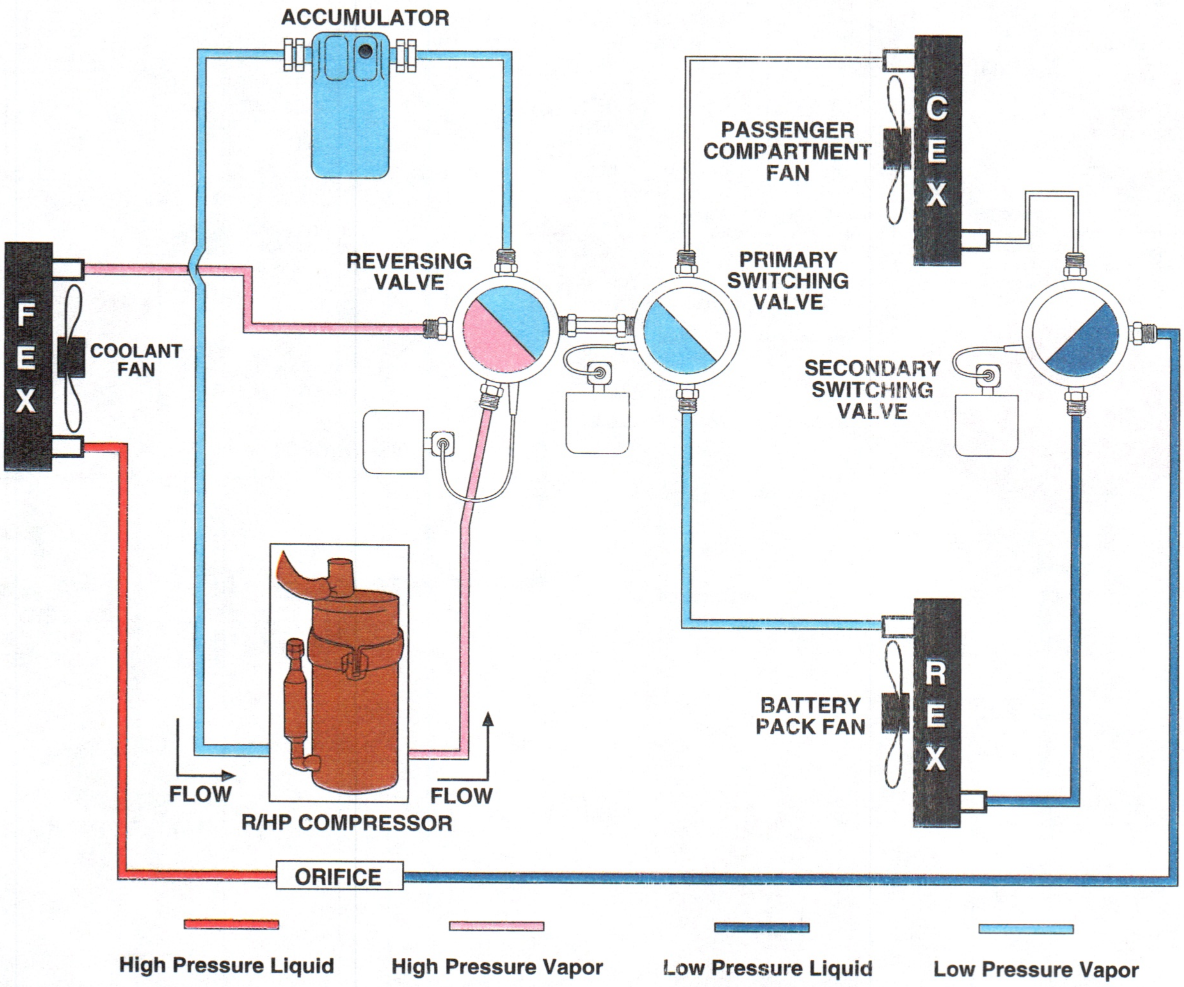

ACCUMULATOR
PASSENGER COMPARTMENT FAN
CEX
REVERSING VALVE
PRIMARY SWITCHING VALVE
FEX
COOLANT FAN
SECONDARY SWITCHING VALVE
BATTERY PACK FAN
REX
FLOW
FLOW
R/HP COMPRESSOR
ORIFICE
High Pressure Liquid
High Pressure Vapor
Low Pressure Liquid
Low Pressure Vapor

Figure 7-16, Refrigeration System — Battery Pack Cooling

Battery Pack Heating

The battery pack thermal management is controlled by the HTCM (see Figure 7-17). The HTCM receives input from the BPCM to heat the battery pack when the temperature exceeds a BPCM parameter. The R/HP system scavenges heat from the outside air at the Front EXchanger (FEX) and transfers it to the Rear EXchanger (REX).

When the HTCM commands the compressor ON, it also commands ON both the coolant fan and battery pack fan. The coolant fan will operate at a slightly higher speed when the compressor is on. The fans help to provide air flow through the exchangers.

During battery pack heating, the refrigerant flows through the R/HP system in the following manner (see Figure 7-18):

- The compressor pushes high pressure vapor to the REX.
- The REX condenses the high pressure vapor into a high pressure liquid by allowing heat from the vapor to transfer to the air entering the battery pack.
- The high pressure liquid is pushed from the REX to the orifice.

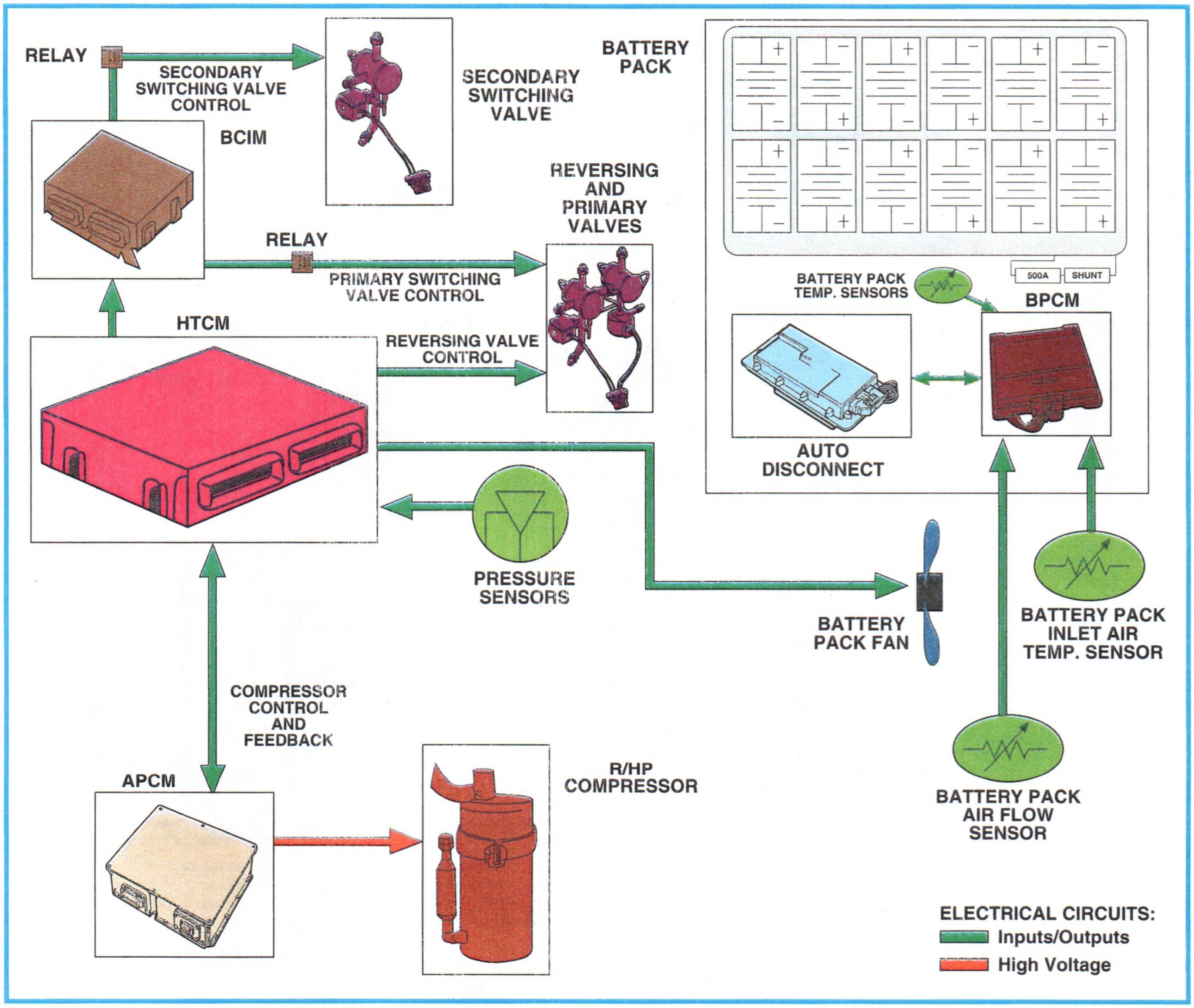

RELAY
SECONDARY SWITCHING VALVE CONTROL
SECONDARY SWITCHING VALVE
BATTERY PACK
BCIM
REVERSING AND PRIMARY VALVES
RELAY
PRIMARY SWITCHING VALVE CONTROL
HTCM
REVERSING VALVE CONTROL
BATTERY PACK TEMP. SENSORS
500A
SHUNT
BPCM
AUTO DISCONNECT
PRESSURE SENSORS
BATTERY PACK FAN
BATTERY PACK INLET AIR TEMP. SENSOR
COMPRESSOR CONTROL AND FEEDBACK
APCM
R/HP COMPRESSOR
BATTERY PACK AIR FLOW SENSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage

Figure 7-17, **HTCM Operation — Battery Pack Heating**

- The orifice provides a restriction for the compressor to push against, and it separates the high pressure side of the refrigeration system from the low pressure side. The lower pressure on the low pressure side of the orifice causes the temperature and pressure of the liquid refrigerant to decrease (due to the pressure-temperature relationship).
- The refrigerant moves from the orifice to the FEX.
- The FEX allows the heat from the outside air to transfer to the low pressure liquid and causes it to change state into a low pressure gas. The coolant fan pulls air through the FEX.
- The low pressure gas moves from the FEX to the accumulator. The accumulator separates any residual liquid from the gas before it enters the compressor.
- The low pressure gas moves from the accumulator to the intake side of the compressor.

The heat battery pack operation is similar to a home heat pump system. The heat is removed from the outside air passing through the FEX and it is released to the air entering the battery pack.

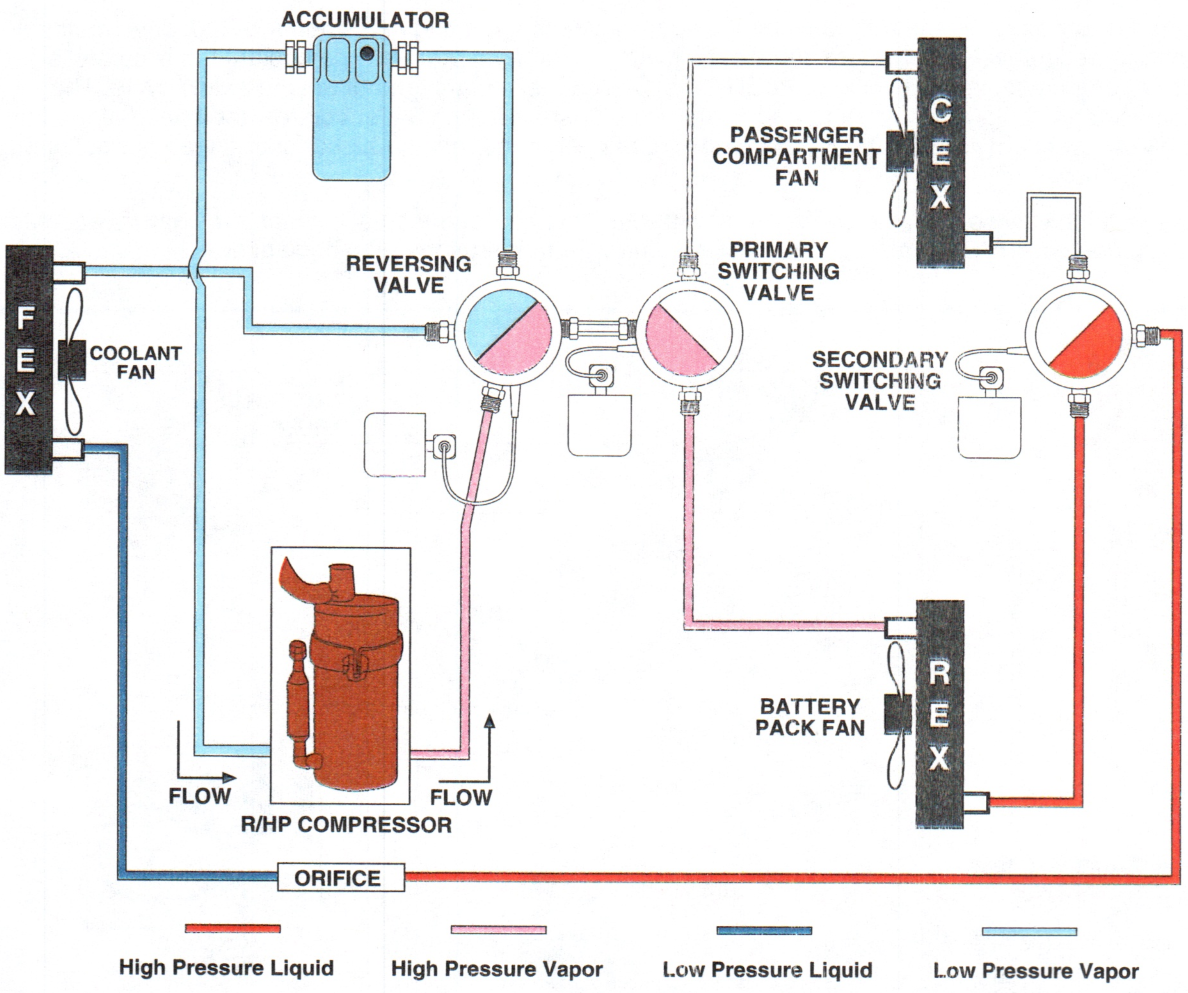

ACCUMULATOR
PASSENGER COMPARTMENT FAN
C E X
F E X
COOLANT FAN
REVERSING VALVE
PRIMARY SWITCHING VALVE
SECONDARY SWITCHING VALVE
BATTERY PACK FAN
R E X
FLOW
FLOW
R/HP COMPRESSOR
ORIFICE
High Pressure Liquid
High Pressure Vapor
Low Pressure Liquid
Low Pressure Vapor

Figure 7-18, **Refrigeration System — Battery Pack Heating**

Coolant System

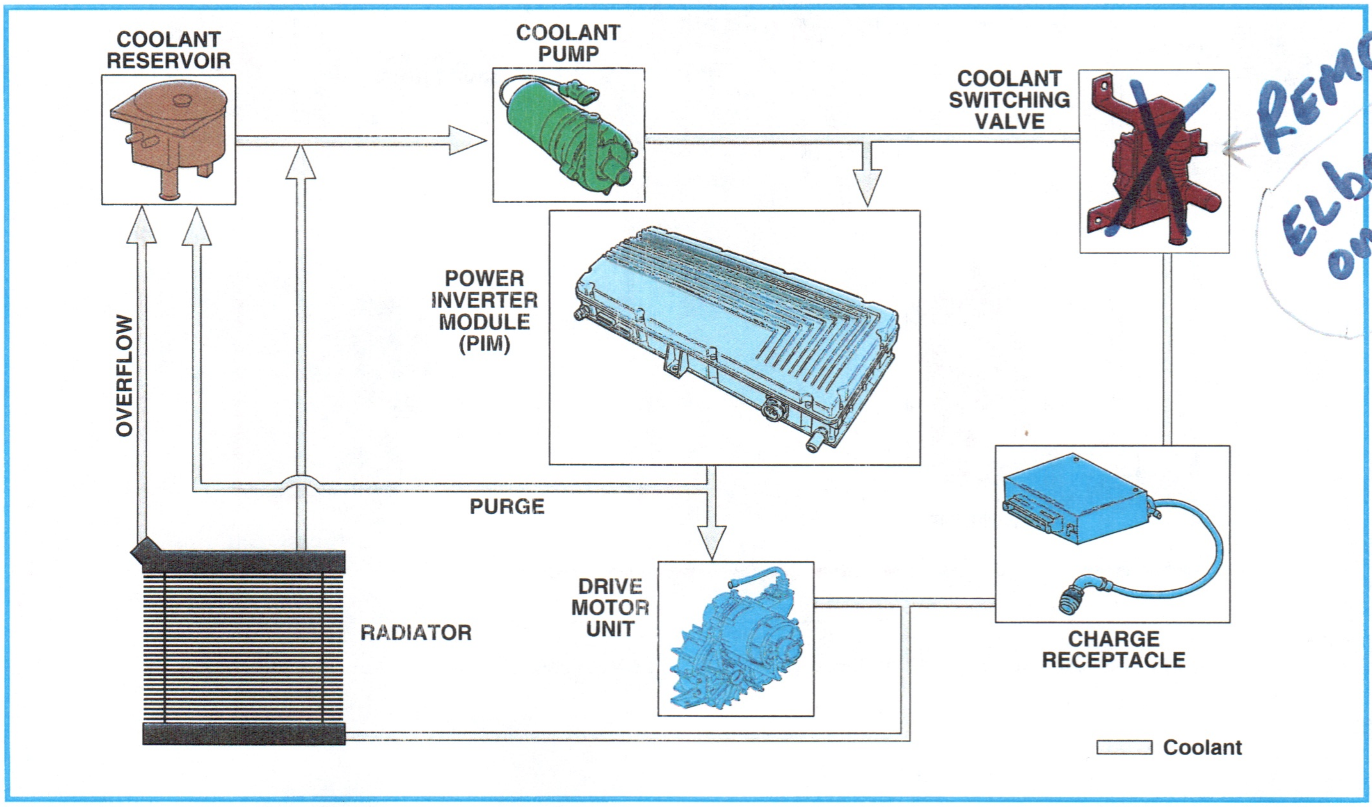
The coolant system is a pressurized (8 psi) system used to remove heat from the PIM, drive motor and the charge receptacle. The coolant system is controlled by the HTCM and has the following components (see Figure 7-19):

- Radiator
- Reservoir
- Coolant Pump
- Coolant Fan
- Coolant Switching Valve
- Temperature Sensors (drive motor winding, charge receptacle, PIM)
- Coolant Level Sensor

The coolant system operates during propulsion and during charging events. When the key is turned to the run position or the BPCM signals the HTCM that charging is occurring, the HTCM turns on the coolant pump. The coolant pump is controlled by the HTCM through a coolant pump buffer. The HTCM provides the coolant pump buffer with a duty cycle. The duty cycle is based on temperature sensors and compressor operation. The buffer controls the speed of the pump based on the duty cycle provided by the HTCM.

The coolant fan is turned on by the HTCM when the compressor is operating and when the PIM, drive motor winding or charge receptacle temperature sensors indicate a rising temperature. The coolant fan is controlled by the HTCM through a coolant fan buffer. The HTCM provides the coolant fan buffer with a duty cycle. The duty cycle is based on coolant temperature and compressor operation. The buffer controls the speed of the fan based on the duty cycle provided by the HTCM. The HTCM will run the fan at a higher speed than normal during compressor operation.

The coolant switching valve allows the coolant to flow through the charge receptacle when the charge receptacle temperature exceeds a BPCM parameter. The HTCM controls the operation of the coolant switching valve.



← REMOVED

Elbow only

Figure 7-19, Coolant System

Charge Receptacle Cooling

During charging, the HTCM can operate the coolant pump and the coolant fan (refer to Figure 7-20). The BCIM (1997) or APCM (1998) provides the power to the pump and fan. Power is provided to the BCIM or APCM on the "wake-up" circuit. The coolant pump will begin operation at the beginning of the charging event. The coolant fan will operate when the compressor is operating or when the charge receptacle temperature rises.

The charge receptacle temperature is monitored by the BPCM. The BPCM provides this information to the HTCM. The HTCM uses the temperature input to control the fan and pump speeds. When the charge receptacle temperature sensor indicates a temperature outside of normal operating temperatures, the BPCM will signal the HTCM to allow fluid to flow through the coolant switching valve to the charge receptacle.

If the coolant level sensor indicates that the coolant level is low, the HTCM will signal the BPCM. The BPCM will then disable charging.

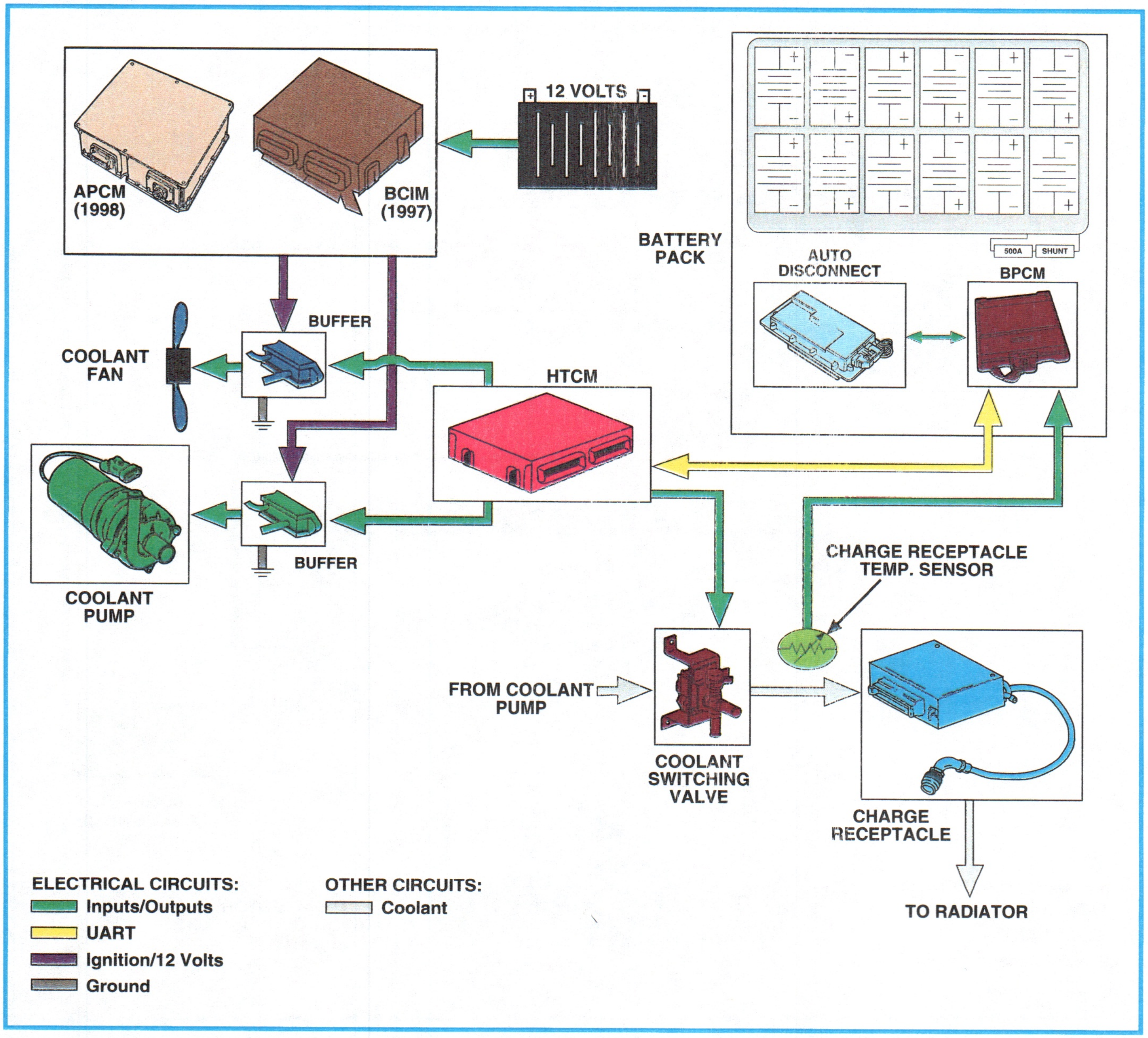

APCM (1998)
BCIM (1997)
12 VOLTS
+
-
BATTERY PACK
500A
SHUNT
AUTO DISCONNECT
BPCM
BUFFER
COOLANT FAN
HTCM
COOLANT PUMP
BUFFER
CHARGE RECEPTACLE TEMP. SENSOR
FROM COOLANT PUMP
COOLANT SWITCHING VALVE
CHARGE RECEPTACLE
TO RADIATOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
🟪 Ignition/12 Volts
▨ Ground
OTHER CIRCUITS:
☐ Coolant

Figure 7-20, **Charge Receptacle Cooling**

7. Thermal Control Systems Operation

Drive Motor System Cooling

During propulsion, the HTCM can operate the coolant pump and the coolant fan (refer to Figure 7-21). The ignition switch provides the power through fuses to both the coolant pump and fan. The coolant pump will begin operation when the key is turned to the run position. The coolant fan will operate when the compressor is operating or when the drive motor and/or PIM temperature rises.

The drive motor winding temperature sensor is monitored by the PIM. The PIM communicates this information to the HTCM on the UART data line. The PIM temperature sensor is monitored by the HTCM. The HTCM uses the temperature input to control the fan and pump speeds. If the temperature exceeds 158°F, the PIM will disable propulsion.

If the coolant level sensor indicates that the coolant level is low, the HTCM will signal the PIM. The PIM can disable propulsion when the coolant level is low.

In 1998, the coolant fan buffer is powered by the 12-volt auxiliary battery.

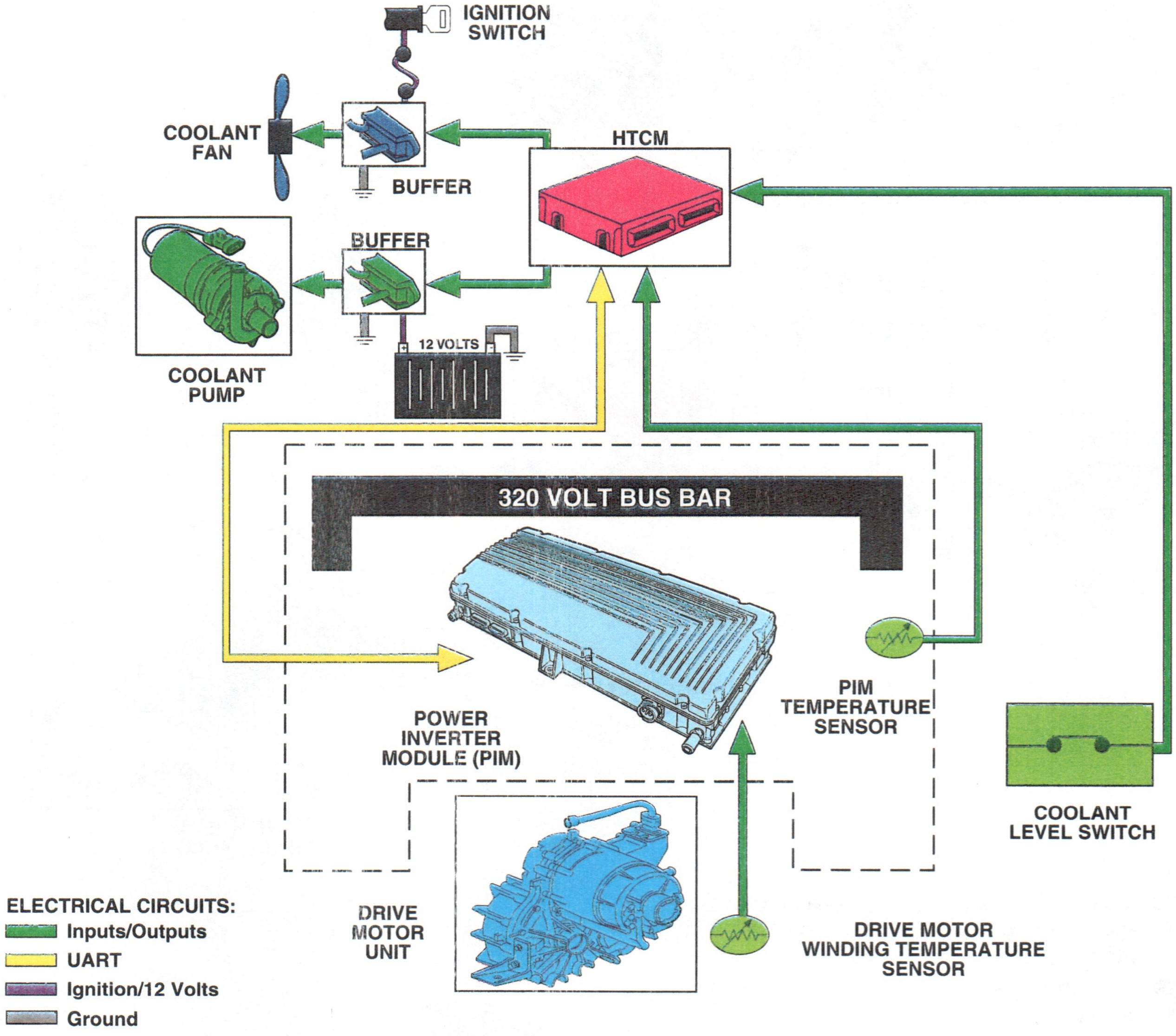

IGNITION SWITCH
COOLANT FAN
BUFFER
HTCM
BUFFER
COOLANT PUMP
12 VOLTS
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
PIM TEMPERATURE SENSOR
COOLANT LEVEL SWITCH
DRIVE MOTOR UNIT
DRIVE MOTOR WINDING TEMPERATURE SENSOR
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟨 UART
▬ Ignition/12 Volts
▬ Ground

Figure 7-21, **Drive Motor and PIM Cooling**

Fuel Fired Heater System

The Fuel Fired Heater (FFH) system is used to provide heat to the cabin when the temperature is below 40°F and the vehicle operator turns the Heat switch ON. The Fuel Fired Heater system has two basic systems: the liquid system and the control system. The following are the components in each system (Refer to Figure 7-22):

- Liquid system (15 psi):
  - Heater Core
  - FFH Reservoir
  - Pump (in fuel fired heater)
- Control system:
  - Heat Switch
  - Heat Switch Lamp
  - HTCM
  - BCIM
  - FFH Relay
  - Fuel Fired Heater Unit
  - Fuel Tank
  - Fuel Level Sensor
  - Fuel Pump
  - Glow Plug
  - Ambient Air Temperature Sensor

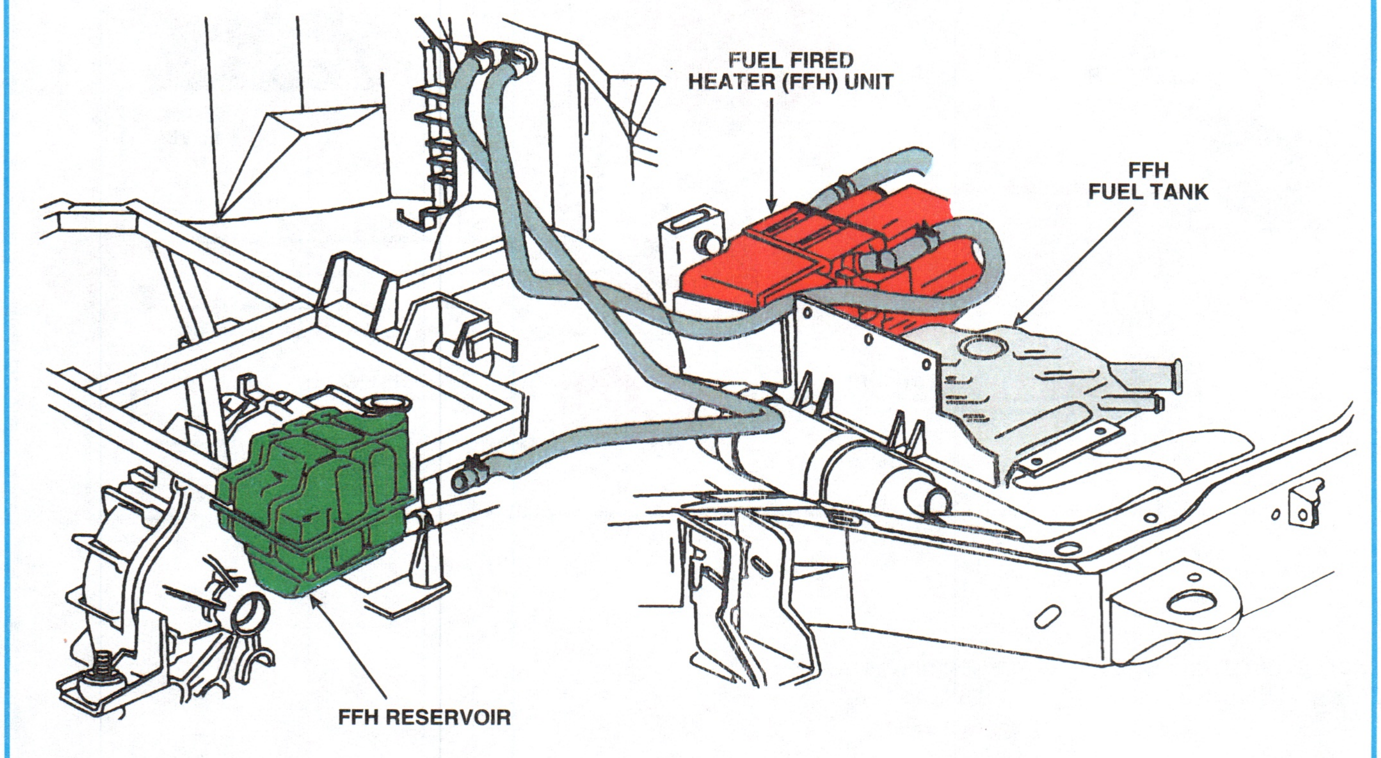


Figure 7-22, **Fuel Fired Heater System**

Fuel Fired Heater System – Continued

When the vehicle operator positions the Heat switch in the ON position, the switch sends a signal to the HTCM (refer to Figure 7-23). If the ambient air temperature indicates that the air temperature is below 40°F, the HTCM will signal the BCIM to start the Fuel Fired Heater. The BCIM will illuminate the Heat switch lamp and energize the FFH relay coil. The FFH relay switch will provide the FFH with power. The FFH will provide power to the glow plug, fuel pump and liquid pump. The liquid pump will push heated liquid from the Fuel Fired Heater to the heater core inside the cabin.

The BCIM monitors the fuel level sensor and the Fuel Fired Heater. If the fuel level is low, the BCIM will illuminate the LOW FUEL lamp in the instrument cluster. The BCIM also provides a FFH fault line to the HTCM. If the HTCM detects a fault in the Fuel Fired Heater, it will signal the BCIM to stop FFH operation and turn off the Heat switch lamp.

It is recommended that the Fuel Fired Heater system be started once a month. Since the temperature will not always be below 40°F, a FFH relay jumper is provided. It is located on the right fender inside the engine compartment next to the power steering pump reservoir. To operate the FFH, a fuse must be inserted into the fuse socket.

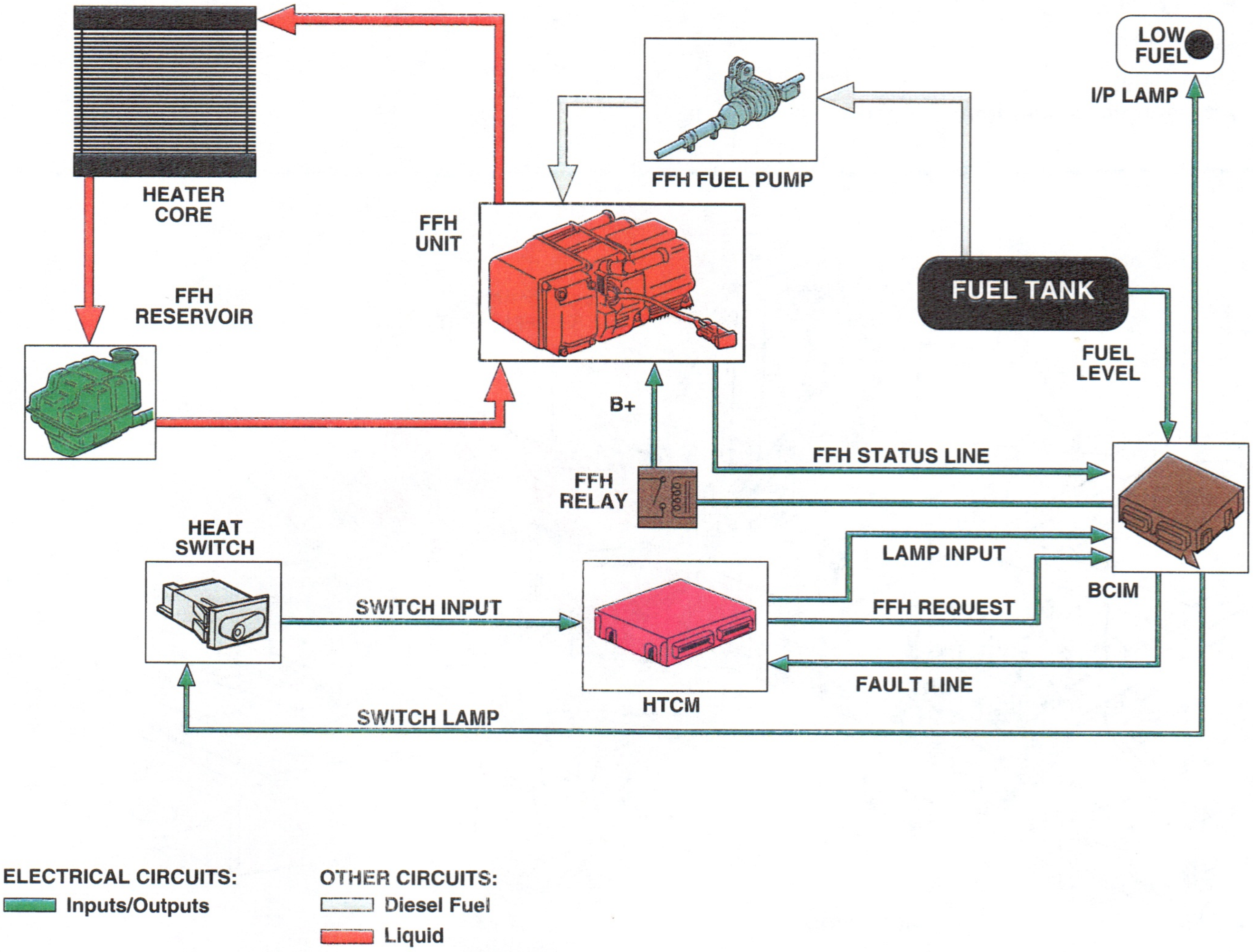

HEATER CORE
FFH FUEL PUMP
LOW FUEL
I/P LAMP
FFH UNIT
FUEL TANK
FFH RESERVOIR
FUEL LEVEL
B+
FFH STATUS LINE
FFH RELAY
HEAT SWITCH
LAMP INPUT
FFH REQUEST
BCIM
SWITCH INPUT
FAULT LINE
HTCM
SWITCH LAMP
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
OTHER CIRCUITS:
☐ Diesel Fuel
🟥 Liquid

Figure 7-23, Fuel Fired Heater System (1997)

Fuel Fired Heater System – Continued

In 1998, the FFH unit no longer provides a fault line to the BCIM. The FFH fault line and lamp input between the BCIM and HTCM is also removed. The lamp inside the FFH switch is automatically illuminated when the contacts of the switch are closed.

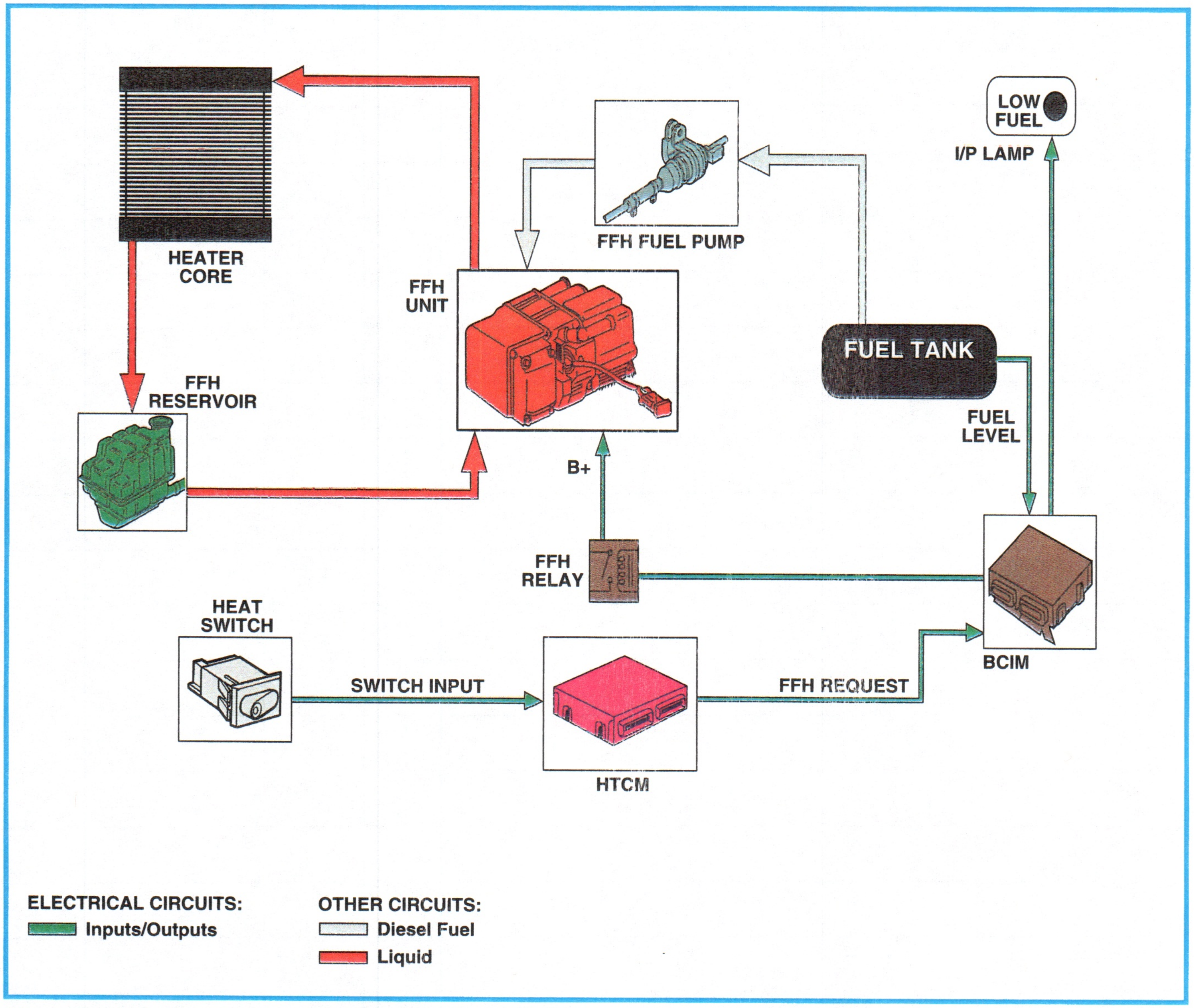

LOW FUEL
I/P LAMP
FFH FUEL PUMP
HEATER CORE
FFH UNIT
FUEL TANK
FFH RESERVOIR
FUEL LEVEL
B+
FFH RELAY
HEAT SWITCH
SWITCH INPUT
FFH REQUEST
BCIM
HTCM
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
OTHER CIRCUITS:
▭ Diesel Fuel
🟥 Liquid

Figure 7-24, **Fuel Fired Heater System (1998)**

Notes

8. Accessory Power System Operation

Overview

The accessory power system provides 12-volt power to the fusible links and the fuse block. The accessory power system receives its voltage from the 12-volt auxiliary battery and the APCM. Prior to the energization of the RUN 2 relay coil, the 12-volt auxiliary battery will provide voltage to the accessory power system. After the energization of the RUN 2 relay coil, the APCM will provide voltage to the accessory power system. The APCM steps-down the voltage from the 320-volt battery pack to the 14 volts that it provides to the accessory power system.

The following are the components of the accessory power system (refer to Figure 8-1):

- 12-Volt Auxiliary Battery
- Accessory Power Control Module (APCM)
- Fusible Links
- Fuse Block
- Ignition Switch
- Accessories (lighting, stop lamps, head lamps and so on)

The 12-volt auxiliary battery is charged by the APCM. During propulsion, the APCM functions like a generator in a gasoline powered vehicle. The APCM uses the voltage from the 320-volt battery pack to charge the 12-volt auxiliary battery. During a charge event, the APCM uses the high voltage available on the high voltage circuit to charge the 12-volt auxiliary battery.

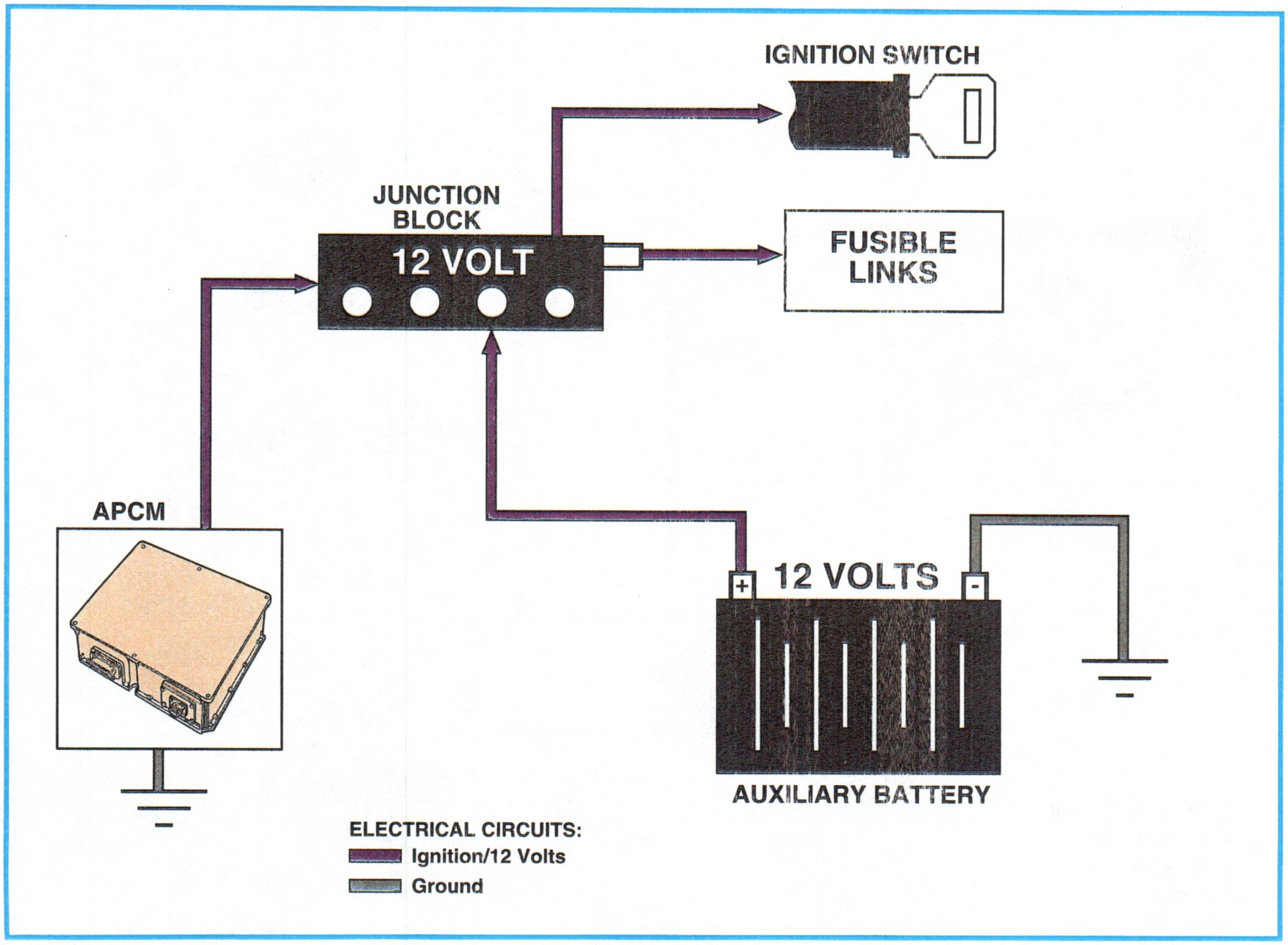


Figure 8-1, **Accessory Power System Block Diagram**

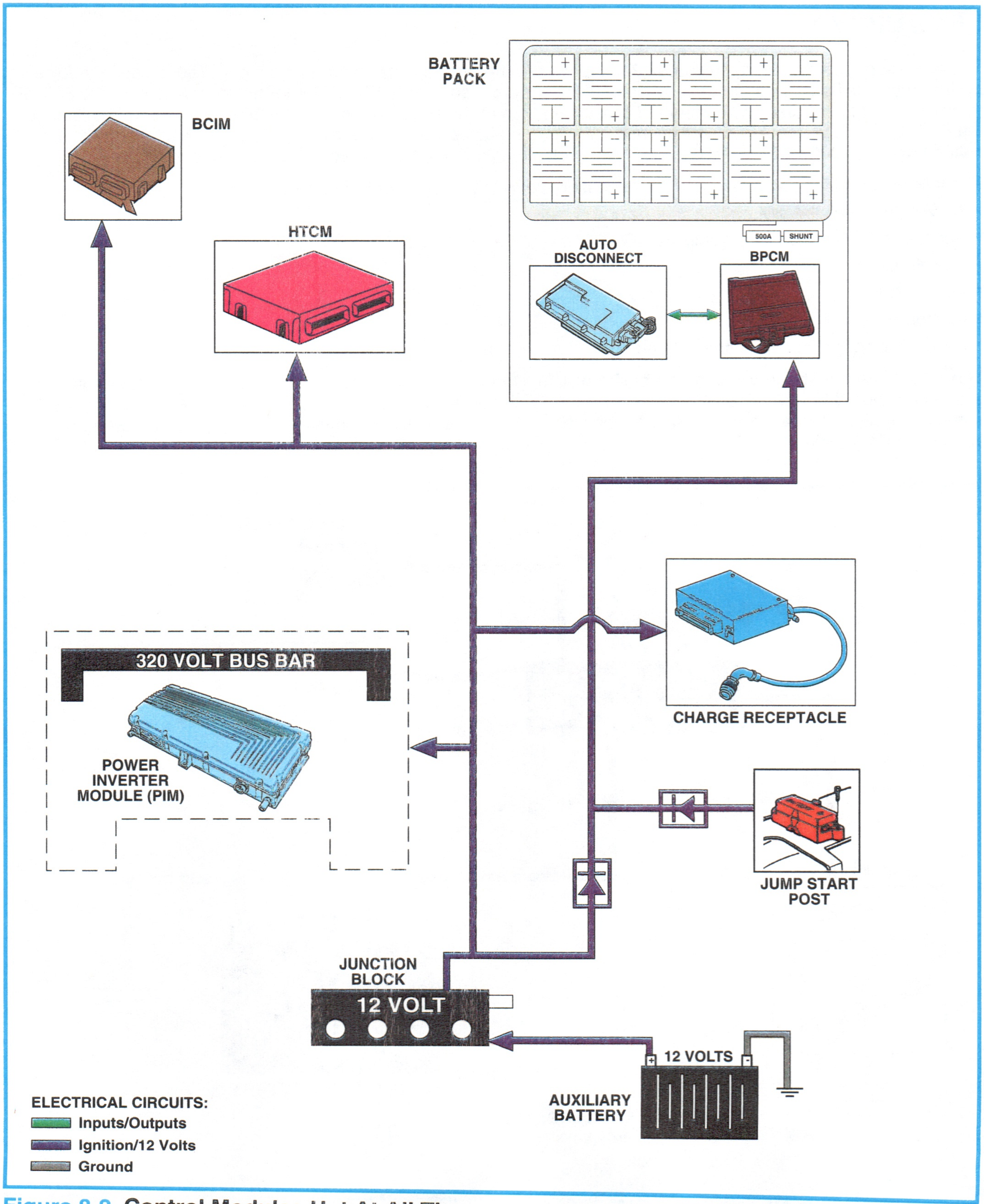

BATTERY PACK
BCIM
HTCM
500A
SHUNT
AUTO DISCONNECT
BPCM
CHARGE RECEPTACLE
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
JUMP START POST
JUNCTION BLOCK
12 VOLT
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟪 Ignition/12 Volts
⬜ Ground

Figure 8-2, Control Modules Hot At All Times

Hot At All Times

The accessory power system provides 12 volts to certain components that must remain Hot At All Times. Prior to the RUN 2 relay coil being energized, this power is provided by the 12-volt auxiliary battery. After the RUN 2 relay coil is energized, this power is provided by the APCM. The following components receive 12-volt power at all times (Hot At All Times):

- Brake Pressure Modulator Valve
- Head Lamps
- Interior Lamps
- Hazard Lamps
- Stop Lamps
- PRND
- Coolant Pump Buffer
- Battery Pack Fan
- FFH Relay and Switch
- DLC
- Chime
- Radio (keep alive memory)
- Horn
- Cigarette Lighter
- DRL Relay

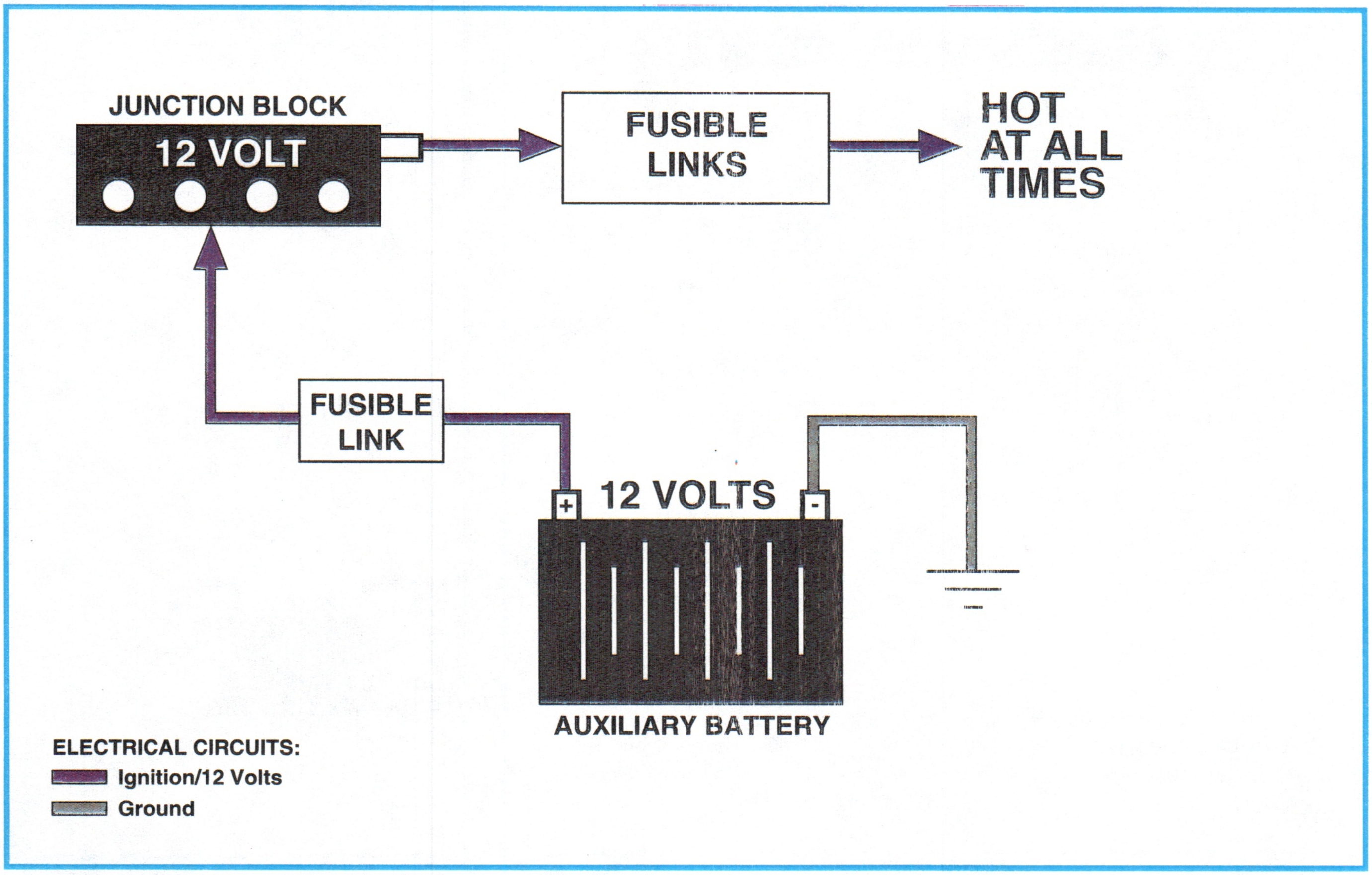

JUNCTION BLOCK
12 VOLT
FUSIBLE LINKS
HOT AT ALL TIMES
FUSIBLE LINK
+
12 VOLTS
-
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Ignition/12 Volts
Ground

Figure 8-3, **Hot At All Times Block Diagram**

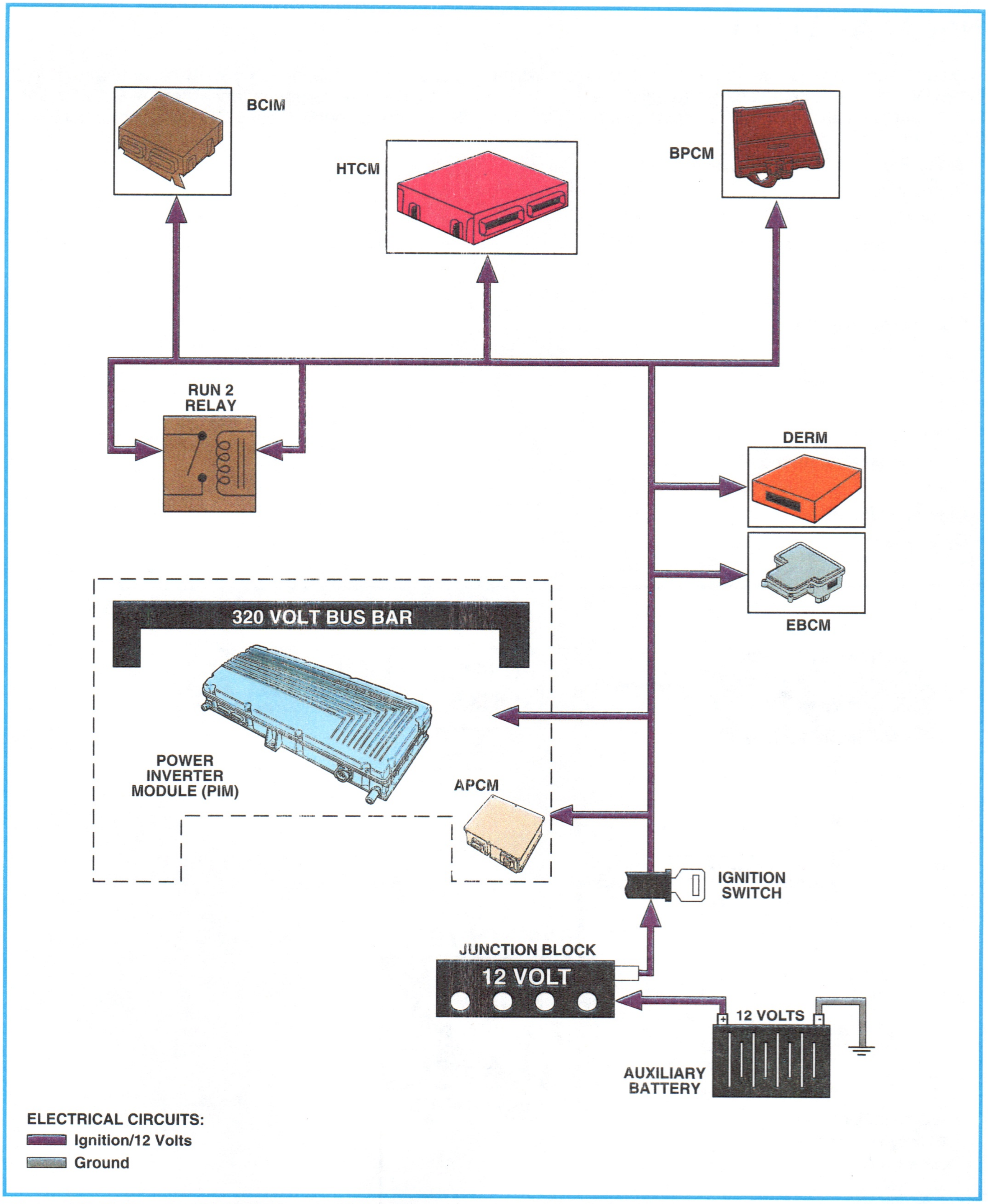

BCIM
HTCM
BPCM
RUN 2
RELAY
DERM
EBCM
320 VOLT BUS BAR
POWER
INVERTER
MODULE (PIM)
APCM
IGNITION
SWITCH
JUNCTION BLOCK
12 VOLT
+
12 VOLTS
-
AUXILIARY
BATTERY
ELECTRICAL CIRCUITS:
Ignition/12 Volts
Ground

Figure 8-4, **Control Modules and Components Hot in Run**

Ignition Switch

The accessory power system provides 12 volts to components controlled by the ignition switch (refer to Figure 8-4). Prior to the RUN 2 relay coil being energized, this power is provided by the 12-volt auxiliary battery. After the RUN 2 relay coil is energized, this power is provided by the APCM. The following components receive 12-volt power in the various ignition switch positions:

- Hot in RUN and ACCY
  - Windshield Wipers and Washers
  - Radio
- Hot in RUN
  - HTCM
  - APCM
  - PIM
  - BPCM
  - BCIM
  - RUN 2 Relay
  - EBCM
  - DERM and Arming Sensors
  - Heater and A/C
  - FFH Switch, Relay and Service Port
  - Coolant Fan Buffer
  - Cruise Control
  - Stop Lamps
  - Instrument Cluster
  - DRL Control Module and Relay
  - Turn Signal Lamp Flasher
  - Chime
  - BTSI Relay
  - Vacuum Pump

Accessory Power Control Module and RUN 2

The RUN 2 relay coil receives a ground path through the BCIM when the HTCM signals that propulsion is enabled (refer to Figure 8-5). The power for the RUN 2 relay coil is provided by the ignition switch in the RUN position. The RUN 2 relay provides the APCM with 12 volts when the coil is energized and the switch closes. When the APCM receives power from the RUN 2 relay, it provides 14 volts to the accessory power system and charges the 12-volt auxiliary battery.

The APCM uses the voltage from the 320-volt battery pack to charge the 12-volt auxiliary battery. The APCM steps-down the voltage from the 320-volt battery pack to 14 volts.

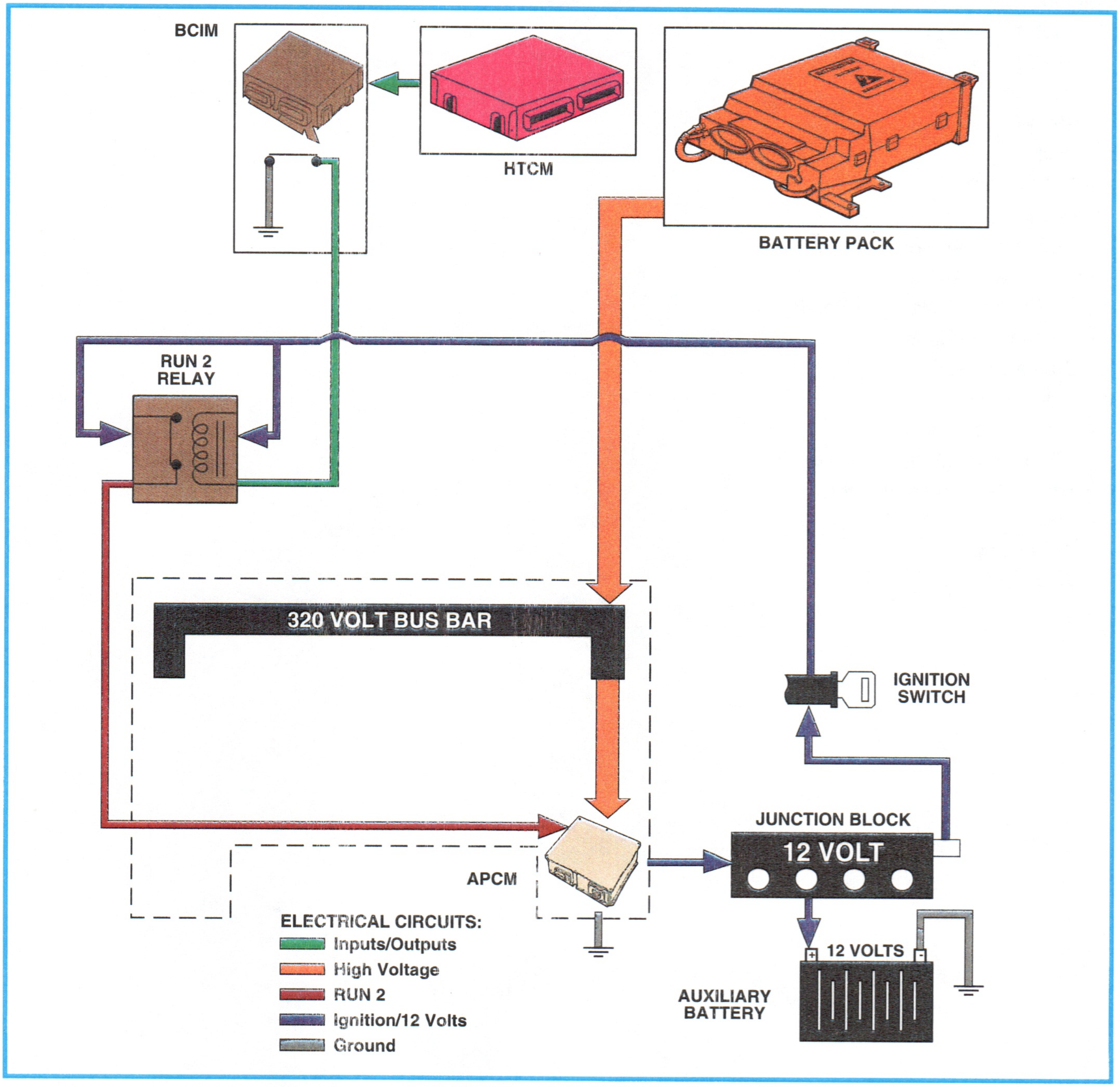
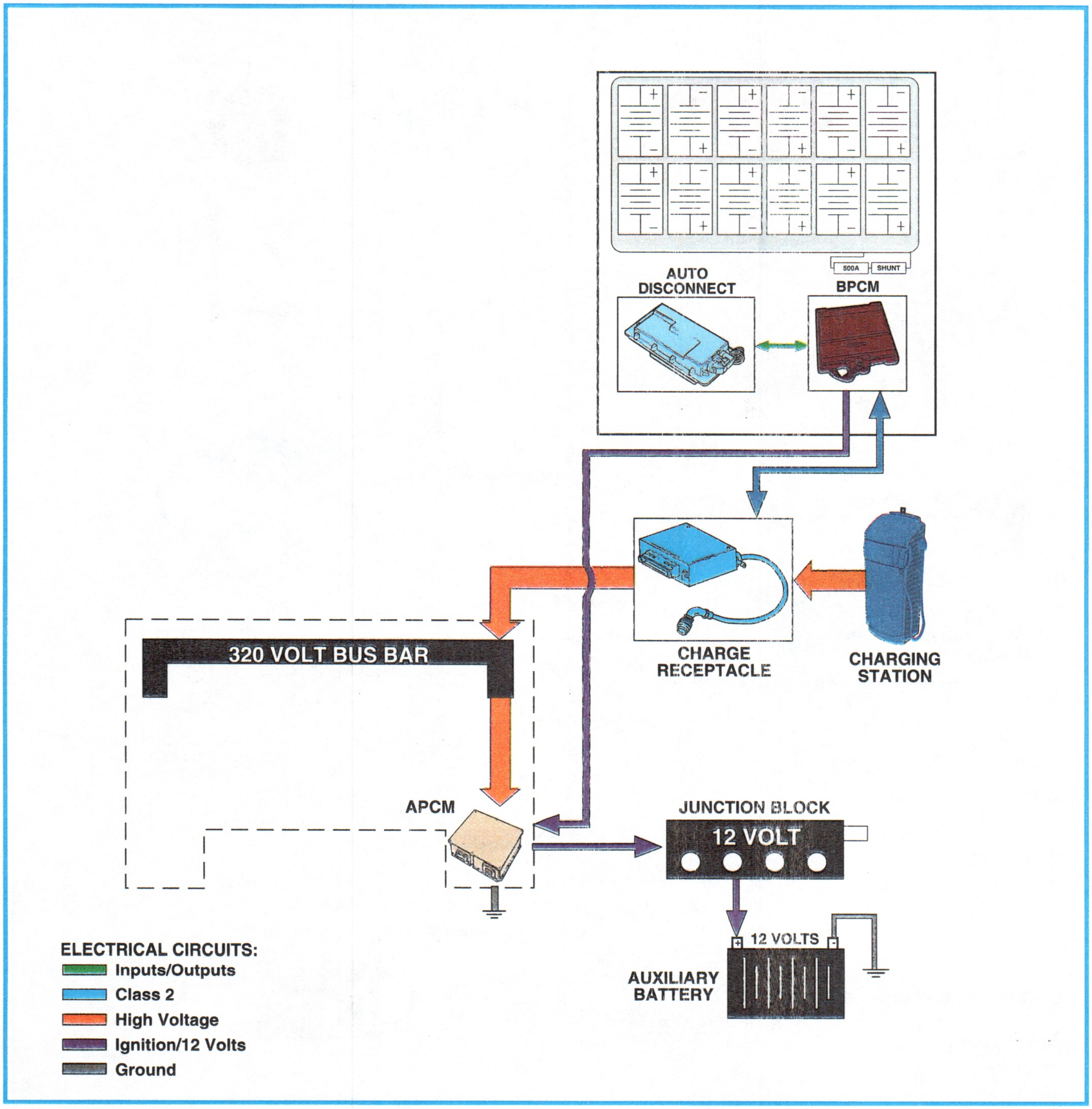

BCIM
HTCM
BATTERY PACK
RUN 2
RELAY
320 VOLT BUS BAR
IGNITION
SWITCH
JUNCTION BLOCK
12 VOLT
APCM
+
12 VOLTS
-
AUXILIARY
BATTERY
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟧 High Voltage
🟥 RUN 2
🟦 Ignition/12 Volts
▨ Ground

Figure 8-5, **APCM and RUN 2**

12-Volt Auxiliary Battery Charging (Paddle Present)

The BPCM will provide a “wake-up” voltage to the APCM when the paddle is present. If the APCM determines that the 12-volt auxiliary battery requires charging, the APCM will use the high voltage available on the high voltage circuit to charge the 12-volt auxiliary battery (refer to Figure 8-6). The APCM steps-down the voltage from 320 volts to 14 volts.

Refer to the Charging System section for more information on the charging event.



500A
SHUNT
AUTO DISCONNECT
BPCM
CHARGE RECEPTACLE
CHARGING STATION
320 VOLT BUS BAR
APCM
JUNCTION BLOCK
12 VOLT
12 VOLTS
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Inputs/Outputs
Class 2
High Voltage
Ignition/12 Volts
Ground

Figure 8-6, **12-Volt Auxiliary Battery Charging During a Charging Event**

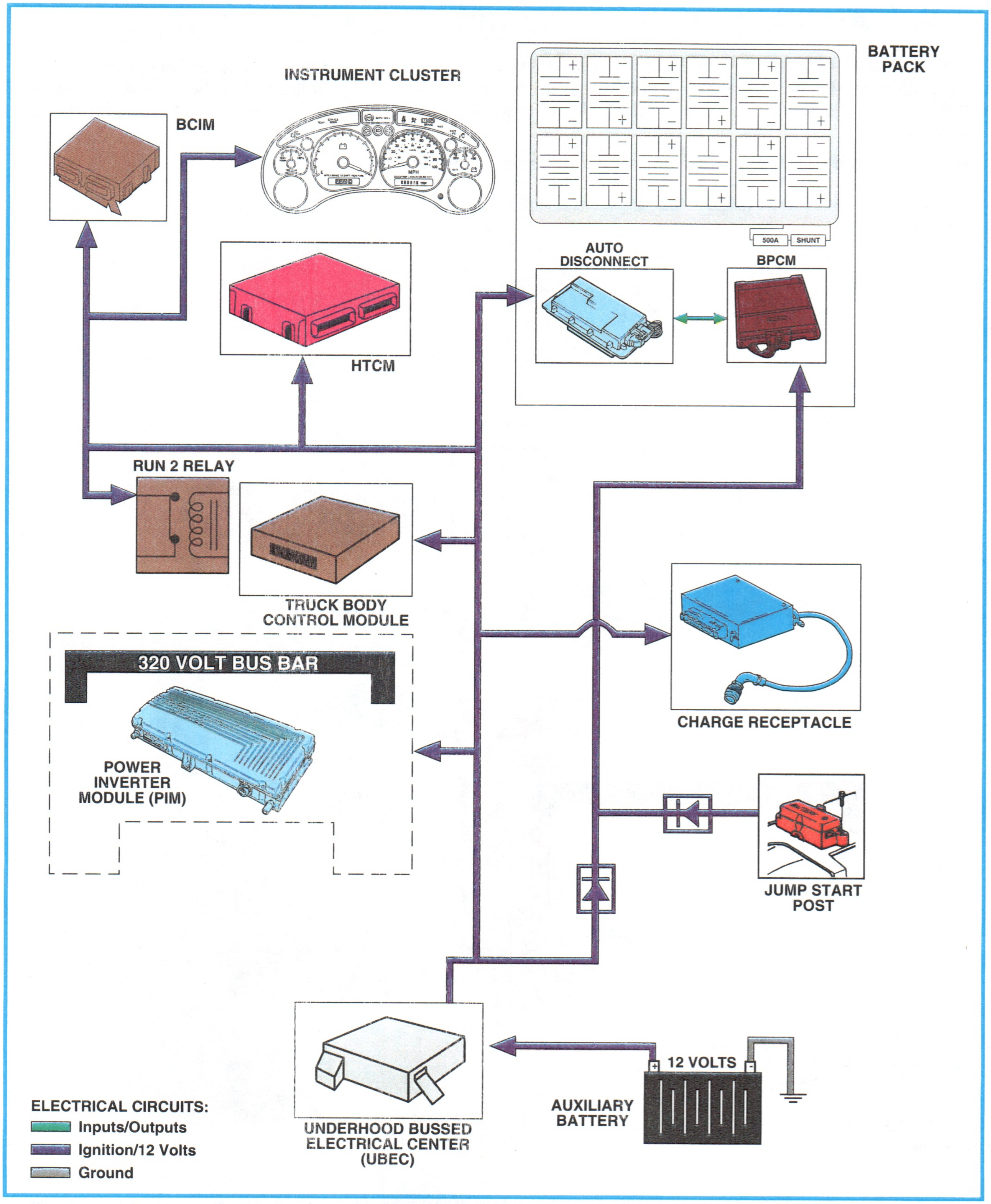
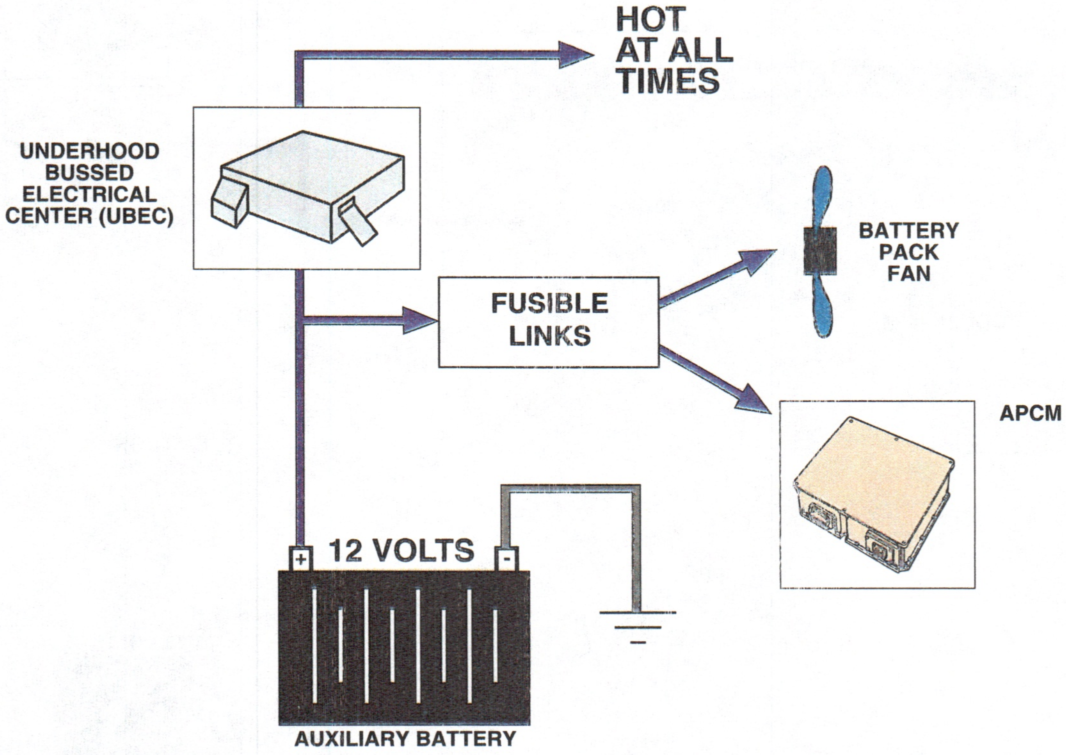

BATTERY PACK
INSTRUMENT CLUSTER
BCIM
500A
SHUNT
AUTO DISCONNECT
BPCM
HTCM
RUN 2 RELAY
TRUCK BODY CONTROL MODULE
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
CHARGE RECEPTACLE
JUMP START POST
12 VOLTS
+
-
AUXILIARY BATTERY
UNDERHOOD BUSSED ELECTRICAL CENTER (UBEC)
ELECTRICAL CIRCUITS:
Inputs/Outputs
Ignition/12 Volts
Ground

Figure 8-7, Control Modules Hot At All Times (1998)

Hot At All Times (1998)

The accessory power system provides 12 volts to certain components that must remain Hot At All Times. Prior to the RUN 2 relay coil being energized, this power is provided by the 12-volt auxiliary battery. After the RUN 2 relay coil is energized, this power is provided by the APCM. The following components receive 12-volt power at all times (Hot At All Times):

- Brake Pressure Modulator Valve
- Head Lamps
- Interior Lamps
- Hazard Lamps
- Stop Lamps
- PRND
- Coolant Pump Buffer
- Battery Pack Fan
- FFH Relay and FFH Unit
- DLC
- Chime
- Radio (keep alive memory)
- Horn
- Cigarette Lighter
- R/HP Valves (Reversing, Primary and Switching)
- Inadvertent Power Relay
- Retained Accessory Power (RAP) Relay
- Blower Motor Relay
- RUN 2 Relay (switch side)
- Coolant Fan Buffer


HOT
AT ALL
TIMES
UNDERHOOD
BUSSED
ELECTRICAL
CENTER (UBEC)
BATTERY
PACK
FAN
FUSIBLE
LINKS
APCM
+
12 VOLTS
-
AUXILIARY BATTERY

ELECTRICAL CIRCUITS:
- ▬ Ignition/12 Volts
- ▬ Ground

Figure 8-8, **Hot At All Times Block Diagram (1998)**

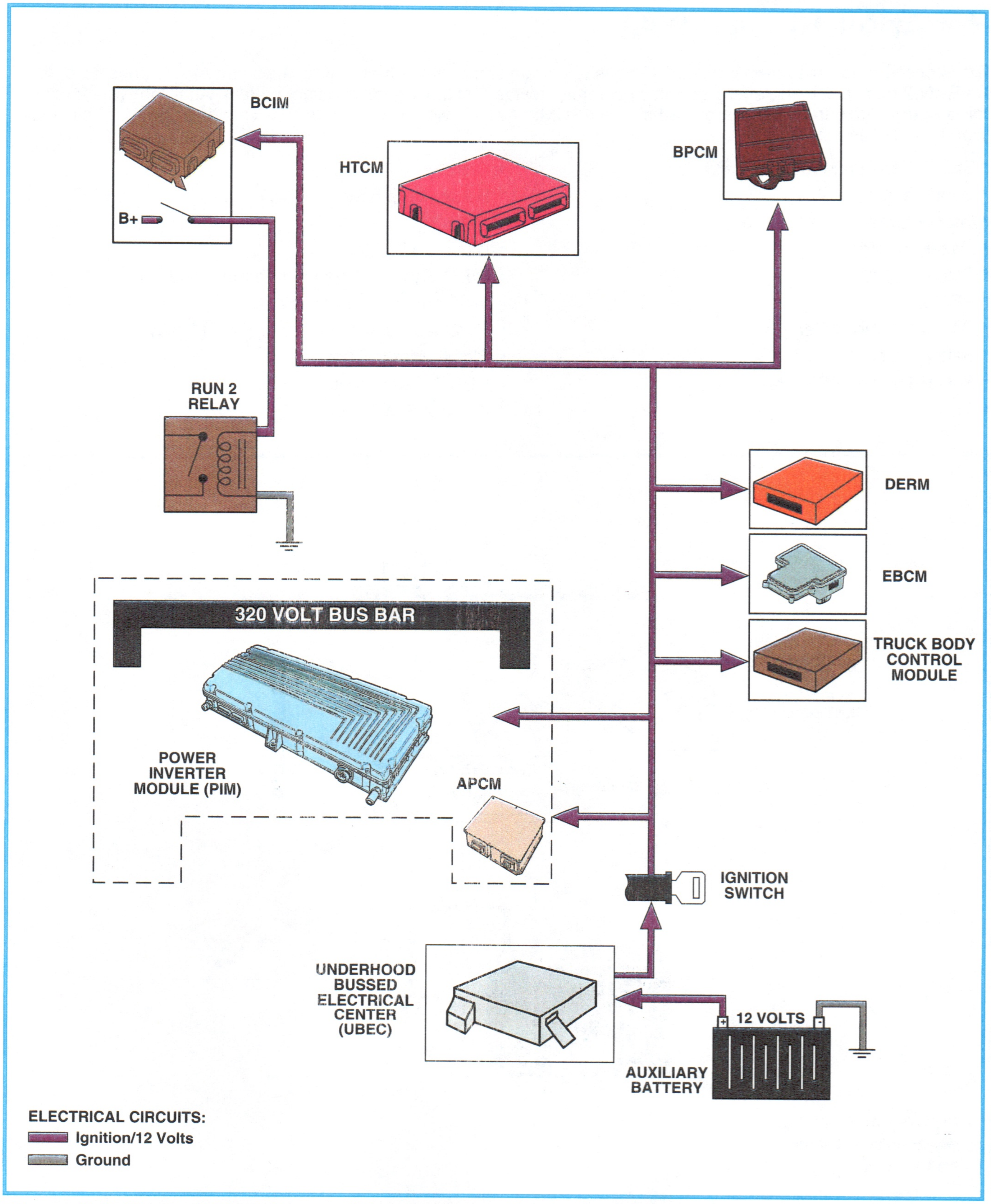

BCIM
B+
HTCM
BPCM
RUN 2 RELAY
DERM
EBCM
TRUCK BODY CONTROL MODULE
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
APCM
IGNITION SWITCH
UNDERHOOD BUSSED ELECTRICAL CENTER (UBEC)
12 VOLTS
+
-
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Ignition/12 Volts
Ground

Figure 8-9, Control Modules and Components Hot in Run (1998)

Ignition Switch (1998)

The accessory power system provides 12 volts to components controlled by the ignition switch (refer to Figure 8-10). Prior to the RUN 2 relay coil being energized, this power is provided by the 12-volt auxiliary battery. After the RUN 2 relay coil is energized, this power is provided by the APCM. The following components receive 12-volt power in the various ignition switch positions:

- Hot in RUN and ACCY
  - Windshield Wipers and Washers
  - Radio
- Hot in RUN
  - HTCM
  - APCM
  - PIM
  - BPCM
  - BCIM
  - RUN 2 Relay
  - EBCM
  - DERM and Arming Sensors
  - SIR Disable switch
  - HVAC
  - FFH Switch, Relay and Service Port
  - Cruise Control
  - Stop switch
  - Instrument Cluster
  - Turn Signal switch
  - BTSI Relay
  - Vacuum Pump
  - Truck Body Control Module

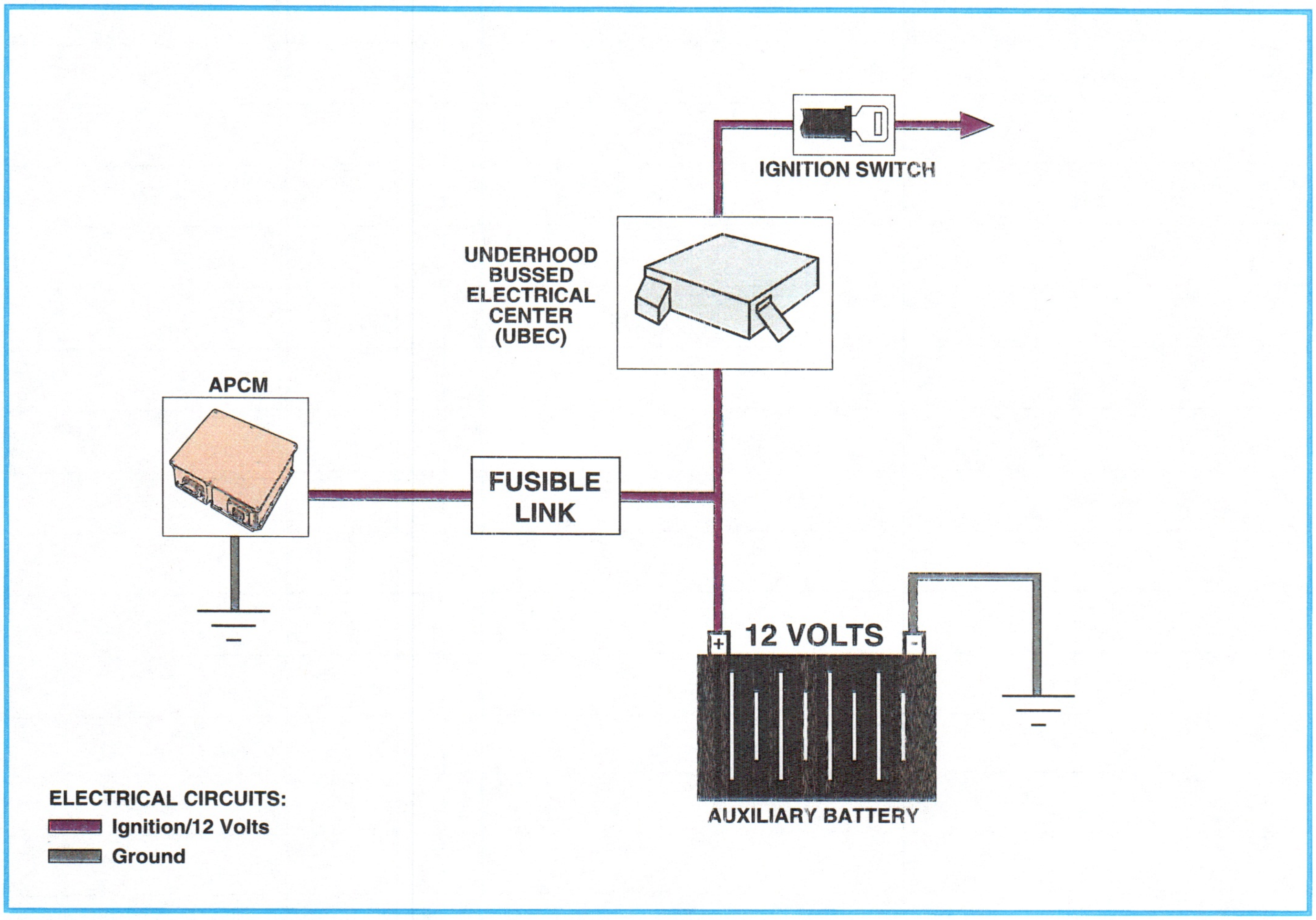

IGNITION SWITCH
UNDERHOOD BUSSED ELECTRICAL CENTER (UBEC)
APCM
FUSIBLE LINK
+
12 VOLTS
-
AUXILIARY BATTERY
ELECTRICAL CIRCUITS:
Ignition/12 Volts
Ground

Figure 8-10, **Ignition Switch Block Diagram (1998)**

Notes

9. Power Steering System Operation

Overview

The Electro-Hydraulic Power Steering (EHPS) pump provides high pressure fluid to the steering gear to assist the driver in turning the front wheels of the vehicle. The EHPS is an AC motor. The EHPS is controlled by the Power Steering Control Module (PSCM), located under the PIM.

After the RUN 2 relay coil is energized, the PSCM will start the EHPS. The PSCM draws current from the high voltage bus in the PIM. The PSCM converts the 320-volt DC on the PIM high voltage bus into 180- to 200-volt AC. The EHPS runs constantly when the RUN 2 relay coil is energized.

The high voltage circuit between the PSCM and EHPS is colored yellow. There is also a high-voltage interlock that follows the EHPS high voltage circuit.

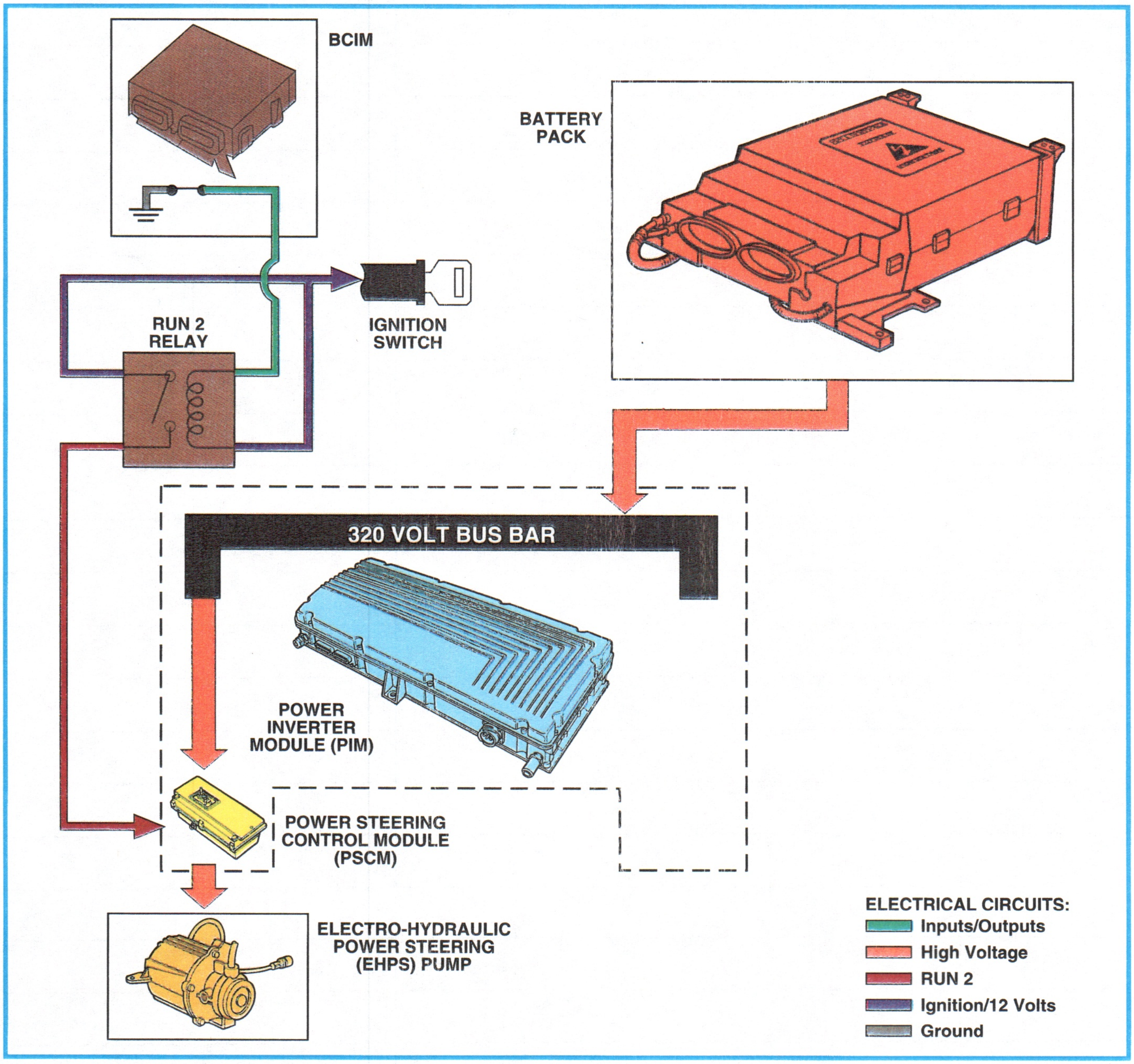

BCIM
BATTERY PACK
RUN 2 RELAY
IGNITION SWITCH
320 VOLT BUS BAR
POWER INVERTER MODULE (PIM)
POWER STEERING CONTROL MODULE (PSCM)
ELECTRO-HYDRAULIC POWER STEERING (EHPS) PUMP
ELECTRICAL CIRCUITS:
🟩 Inputs/Outputs
🟥 High Voltage
🟥 RUN 2
🟪 Ignition/12 Volts
⬜ Ground

Figure 9-1, Power Steering Control Block Diagram

Notes

Glossary of Terms

ABS	Antilock Brake System
AC	Alternating Current
A/C	Air Conditioning
APCM	Accessory Power Control Module
APP	Accelerator Pedal Position sensor
BBEC	Body Bussed Electrical Center
BCA	Bias Control Module (located inside the PIM)
BCIM	Body Control Interface Module
BPIAT	Battery Pack Inlet Air Temperature sensor
BPCM	Battery Pack Control Module
BTU	British Thermal Unit
CCM	Convenience Charge Module
CEX	Cabin EXchanger
DERM	Diagnostic Energy Reserve Module
DC	Direct Current
DLC	Data Link Connector
DMCM	Drive Motor Control Module (located inside the PIM)
DMSD (encoder)	Drive Motor Speed and Direction sensor
DMU	Drive Motor Unit
DRL	Daytime Running Lamps
DTC	Diagnostic Trouble Code
EBCM	Electronic Brake Control Module
EHPS	Electro-Hydraulic Power Steering pump
FEX	Front EXchanger

Glossary of Terms, continued

FFH	Fuel Fired Heater
HTCM	Heating and Thermal Control Module
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
HVIL	High Voltage Interlock Loop
IGBT	Insulated Gate Bi-polar Transistor (Located inside the PIM, APCM and PSCM)
IGN	IGNition Switch
IP	Instrument Panel
KPA	KiloPascal
OCM	Opportunity Charge Station
PIM	Power Inverter Module
PSCM	Power Steering Control Module
REGEN	Regeneration (Regenerative Braking)
REX	Rear Exchanger
RF	Radio Frequency
R/HP	Refrigeration/Heat Pump system
SCM	Standard Charge Module
SOC	State-Of-Charge
TBC	Truck Body Control module
TR switch (PRND)	Transmission Range switch
UART	Universal Asynchronous Receive and Transmit
UBEC	Underhood Bussed Electrical Center

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